LOCAL MATERIALS

MATERIALS OF THE FUTURE

LOCAL RESOURCES FOR SUSTAINABLE

CITIES AND TERRITORIES IN AFRICA

CRAterre Éditions

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CRAterre

Produced with the support of

MINISTÈRE DE L'EUROPE ET DES AFFAIRES ÉTRANGÈRES

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Warning

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PREFACE

The Covid 19 pandemic has underlined the benefits of short and resilient production chains. This is similar to the way the 1973 oil crisis revived interest in local building materials, often plentifully available and consuming little oil. I am thinking here in particular of earthen architectures, the subject of a remarkable exhibition at the Centre Georges Pompidou in 1981: “L’avenir d’une tradition millénaire”[1]. Earth is indeed a natural material available in abundance and lending itself to construction.

Africa, a priority region for French official development assistance, faces the huge challenge of housing millions of people in decent conditions and adapting to climate change. Local building materials can make a significant contribution, if they are collected responsibly, used in accordance with best practices and suitably recycled. Such production chains also provide another benefit in terms of development: they create local jobs for the necessary maintenance of the buildings constructed. In this respect, it is not so much a matter of preserving traditional know-how as of promoting tried and tested techniques, particularly through prestigious public or private operations, and improving their image.

I therefore welcome this work which aims, through the presentation of actual constructions currently in use, to encourage increased use of local building materials, in accordance with the resources available and with habits and customs.

I hope that it will encourage transition to a larger scale beyond pilot projects and facilitate a revival of solutions suited to today’s needs.

Philippe LACOSTE
Director for Sustainable Development
Ministry for Europe and Foreign Affairs

1. “Architectures de terre ou l’avenir d’une tradition millénaire”, édition du Centre Georges Pompidou, Paris, 1981, also shown as “Down to earth: mud architecture, an old idea, a new future”, London: Thames and Hudson, 1982

PREFACE

This publication supported by the French Ministry for Europe and Foreign Affairs simultaneously provides answers both to questions of education, science and culture and, beyond that, to concerns which have been of particular importance to UNESCO since the end of the last century: cultural diversity and trust of local players in their own productions and knowledge. This has been materialised in particular by its backing for the creation of the UNESCO Chair for Earthen Architecture, Building Cultures and Sustainable Development at the Ecole Nationale Supérieure d'Architecture in Grenoble.

It is now widely recognised that the major global challenges of our time, as described in the Sustainable Development Goals adopted by all member states of the United Nations in 2015, will only be met if, in addition to governments, the whole population plays its part. This will be all the easier if the population can do this by relying on its own strengths and abilities and on the resources it can find in its nearby environment.

It is indeed from this perspective that, in the construction sector and more broadly the housing sector, the concept of local materials appears particularly promising. By proposing to focus research and training in this sector, and by promoting already tried and tested technical solutions, accessible to the majority of the population, we can give those most in need every opportunity to meet today's challenges in an appropriate way, both locally and globally, and to respond to the risk linked to continuing climate change.

The concept of local materials means of course the results of scientific and technical research, but it also means a huge potential for the valorisation of local building cultures. Almost everywhere in Africa there are original and intelligent solutions for people to build their habitat with the natural resources available locally. Almost everywhere too, knowledge and know-how exist and need only to be adapted to provide an answer, possibly as a complement to industrial solutions, to housing needs and land use planning needs in general.

Traditional architectures also very often provide particularly interesting examples of bioclimatic architecture. Similarly, the modes of inhabiting and urban planning concepts behind traditional human settlements also frequently present very particular benefits favouring good integration of individuals and families and good organisation of the social life of the community, or of the communities present in the same urban centre. Management systems encouraging mutual assistance and community input also present particularly interesting potential for technical efficiency while at the same time greatly reducing housing production costs and also maintenance costs.

It is not of course a question of going back to the past but, for the whole of Africa and the communities which compose it, of not losing all the good inventions which have arisen in various places in the course of its rich past, already often combining local experience(s) and outside inputs.

I hope that this publication can be widely disseminated to assist in the development of a suitable living environment and even greater resilience for the populations of Africa.

Lazare ELOUNDOU ASSOMO
Director for Culture and Emergency Situations at UNESCO

Diapalante Centre, Saint Louis, Senegal
Architects: Suzanne Hirchi and Laurent Biot
Company: #ELEMENTERRE

FOREWORD

This publication on local building materials concerns the issue of "sustainable cities and territories" raised by numerous players internationally, particularly in France and on the African continent. This approach, because beyond the simple question of materials we are indeed talking about an approach, is intended to be in line with the Sustainable Development Goals and to contribute directly to several of them.

The publication is intended primarily for "Habitat" decision-makers and officials in ministries and local and regional authorities and for other stakeholders in the sector (craftsmen and entrepreneurs, professional organisations, academic and professional training centres, research centres, NGOs, etc.) involved in and concerned by the question of producing a more sustainable built environment that is accessible to all.

The aim of this publication is to provide as full an overview as possible of local materials and their use in Africa, based in particular on recent experiences and projects in Africa, without seeking to be exhaustive, which would have required a much more substantial work. A choice was made to deliberately highlight the continent's major contribution to the question in the context of the challenges represented by construction needs over the next few decades due to Africa's demographic and urban growth.

For this purpose, the work presents in a concise and educational way the benefits and limitations together with the questions which are raised and the prerequisite conditions for the use of these materials in a sustainable and contemporary framework. In addition to examples of technical solutions illustrated by an overview of the potential (bio-based and geosourced) resources of the territories concerned, it provides some elements for analysis of the impact of local short production chains and some methodological elements. It also highlights the need for matching between architectural design and the specific characteristics of the materials available locally, which could be summarised as "the right material in the right place".

INTRODUCTION

In response to the urgent need for solutions to social and environmental challenges, almost everywhere in the world the construction sector is attempting to adopt new, more sustainable ways of building. This is particularly the case in Africa, which continues to have high demographic growth leading to huge future needs for housing.

In this context, the concept of local materials, which first began to emerge in the late 1970s, is becoming increasingly relevant on this continent. The term "local" immediately evokes the idea of availability and proximity, and therefore savings, while the term "material" implies the idea of a raw material which has to be processed before being used, with possible reuse or recycling at the end of its life, which brings this concept in line with the more recent concept of a "short supply chain".

Justice and Peace Commission, Ougadougou, Burkina Faso. Architect: Sayouba Tiemtoré

The use of local materials in construction can be defined as follows: "Prioritising locally available material and human resources when building a habitat, with beneficial effects on the economic, social, cultural and environmental level, both locally and globally."

These local materials are the result of the processing or assembly of one or more natural resources extracted near the site of construction. Ideally, they require little processing to constitute elements or components able to perform various functions (supporting, insulating, roofing, etc.) in a given building with maximum saving of non-renewable energy for its construction and then its use. They can be classified in two main categories:

- "bio-based" materials of plant or animal origin - the matter which constitutes them is obtained from biomass;
- "geosourced" materials of mineral origin - the matter which constitutes them is obtained from the geological or soil layers of the Earth's crust.

"Local materials" also refers to the idea of what is done locally. This is of course what man has done all over the world since the dawn of time. In Africa, the materials used are very diverse in their characteristics and their uses, which has led

to highly varied rural or urban habitats. The knowledge and know-how associated with them may be the result of very ancient traditions, but also of more recent practices. Some of them are also the result of cultural exchanges which have injected ideas for renewal and innovation.

Under the influence of globalisation, these practices have however tended to disappear. In spite of this, these “traditional” building abilities constitute an important source of innovations which can play a major role as a substitute or complement for industrial or “thermo-industrial” materials which require processing steps involving considerable consumption of energy and production of greenhouse gases and waste, some of which is highly polluting.

Local materials offer many benefits in terms of environmental impact, performance and comfort. Made from natural substances, they are also often beneficial for the health of inhabitants. But they cannot necessarily meet all uses. They must therefore be used logically, based on the principle of the right material in the right place.

The possibilities in terms of hybridisations or combinations remain little explored. We may nevertheless imagine that there are many such possibilities, promising a large number of innovations in the coming years in response to the urgent need for a social and environmental transition all over the world, and of course on the African continent. The aim of this work is to highlight a number of examples of such approaches which could inspire many others in the years to come.

1

LOCAL MATERIALS: A HISTORICAL PERSPECTIVE

The origin of habitats: local materials

In his quest to protect himself from the elements and external threats, to provide himself with privacy and comfort, but also to develop his activities, man has, in the course of history, built a wide variety of habitats, from the simplest shelter to the most sophisticated urban complexes, using locally available materials. Depending on the territory, the resources present nearby and the geographical specificities, but also according to the social and cultural practices and the needs and means specific to each community or society, these habitats have taken unique and highly varied forms. Much of our built heritage has been shaped using construction techniques and knowledge associated with materials obtained from the transformation of local mineral, plant and animal resources. These building techniques were perfected over time, often through processes of experimentation, to meet new needs or challenges.

From local materials to industrial materials

With the advent of new production and construction processes in the industrial era, new construction technologies emerged and spread on a global scale. From the end of the 19th century onwards, a certain "disruption" occurred. Although they still persist in many places, "traditional" building cultures have seen their fields of application diminish or even disappear in some cases, together with the associated knowledge. In difficult-to-access areas or when they are strongly rooted in local practices, these cultures continue to exist. In many places, local materials co-exist with "thermo-industrial materials". Local materials still today represent an essential resource for housing a large proportion of humanity.

Materials for building differently

In the face of the energy crisis in the early 1970s and the search for new social, economic and philosophical models, initiatives were launched to produce "differently" and to consider local materials as viable alternatives to energy-intensive building techniques. Raw earth and bioclimatic construction, to cite only these examples, spearheaded this renewal. In Europe, in Africa and in other places in the world, a lot of experimentation and research was conducted with a view to updating local materials and "traditional" building techniques.

"Appropriate technology": an attempt at renewal

From the 1970s, a movement for "appropriate technology" in construction developed with numerous projects, some of which already aimed to set up fully-fledged sectors. These experiments found applications in technology transfer policies which were part of bilateral cooperation arrangements or United Nations programmes (including ILO, UNDP or UNCHS initiatives). Many of these actions and projects concerned African countries, like the LOCOMAT project in Burkina Faso. This "prosperous" period led to the production and dissemination of new scientific and technological knowledge based in particular on the compressed stabilised earth block (CSEB) technique or the reintroduction of traditional architectural forms for roofs, as in the case of the *Woodless Construction* project developed by *Development Workshop* in the Sahel region. An international network[1] was even created at the end of the 1980s with the aim of providing advice and disseminating information on appropriate technologies for construction.

It was also in this period that France launched a large-scale public infrastructure and social housing programme in Mayotte where more than 10,000 earthen housing units and 1,000 earthen public buildings were built between 1982 and 1988. The Domaine de la Terre, an OPAC38 project to build 65 social housing units, was launched in Villefontaine (Isère, France) in the same period.

1 BASIN (Building Advisory Service and Information Network), a network which is now defunct.

From enthusiasm to questioning

At the turn of the millennium, with the end of the *Global Strategy for Shelter* promoted by the United Nations, enthusiasm for "appropriate technologies" died down. Initially perceived as the solution to the problem of access to decent housing for all, this approach has failed to achieve the expected results. Despite a few notable successes, it came up against realities in the field highlighting the inadequacies and weaknesses of the projects. Too disconnected from local realities and imposed "from above", "appropriate technologies" were often a highly technical solution suffering from a lack of consideration of local social and economic issues. Incorrect sizing of projects due to a failure to take into account the skills available and the timescales necessary for learning and development of skills prevented the desired objectives from being reached. This situation ended up leading to frustration which eventually impacted the momentum of local materials.

Drawing the lessons: from "local materials" to "local building cultures"

In spite of everything, this phase allowed people to develop very important knowledge, re-examine approaches and draw lessons for the future. These lessons can be summarised as follows:

- often decontextualised solutions, with insufficient taking into account of local social, cultural, technical and economic specificities;
- incorrect or incomplete starting hypotheses (e.g. "simple" techniques requiring little or no expertise) based on preconceived ideas or a lack of references;
- incorrectly sized projects in which the matching between objectives and means had not been correctly evaluated;
- constructions in "improved" local materials which are less expensive than conventional constructions but which remain unaffordable for the majority of people compared to the solutions used by the informal artisanal sector;
- unfavourable methods of calculation which do not take into account indirect costs and the aid from which competing sectors benefit;
- excessive technical innovations compared to local practices, introducing a degree of complexity which is unnecessary or difficult to assimilate over a short period of time;
- initiatives often exclusively focused on the most disadvantaged populations, contributing to an image of poor materials for the poor;
- in spite of everything, iconic projects and a high potential to meet challenges in terms of sustainable human settlements.

This very rich period provided an example of a very "product-oriented" and not at all "process-oriented" positioning and project logic, and of a quest for a universal technical solution which applies to all situations.

From this realisation emerged the idea of integrated approaches based on an understanding of the context and the need to proceed iteratively, in successive steps, alternating phases of study, design, implementation and evaluation through various complementary activities in order to progressively create the conditions for the success of the project.

This necessarily requires, among other things, involvement of stakeholders, reinforcement of local capacities and promotion and awareness operations. From a socio-technical point of view, this means better taking into account of local knowledge and know-how, social dynamics and pre-existing modes of inhabiting in the areas concerned. It was this realisation which was to form the basis for the "local building cultures" approach.

TOWARDS A RENEWAL OF LOCAL MATERIALS GAUGED AGAINST SUSTAINABLE DEVELOPMENT GOALS

Over the past ten years, we have witnessed a comeback of local materials, as they benefit from a much more favourable framework and context. On the one hand, scientific knowledge has greatly progressed and is much more solid: local materials are subjects of research and have gained in recognition and maturity. On the other hand, awareness of the reality of the climate change and acute needs for sustainable housing resonate with soft, sustainable, balanced and local approaches developed around local materials. The threat posed to natural and human environments by existing building practices, together with their socioeconomic consequences, accentuates the interest taken in materials and techniques in line with sustainable development goals.

Increasing international recognition

This renewed international interest on the part of many players (architects, local governments, public institutions, companies, etc.) is profoundly changing the image of local materials and so-called “vernacular” techniques. Even if this trend is more clearly apparent among more affluent population categories and in “rich” countries, these materials are now presented from a resolutely contemporary perspective, combining tradition and modernity and being in line with a sustainable approach.

Over the past few years, in France and in the rest of Europe, interest in local materials has been stronger than ever on the part of public authorities[1] which support or participate in numerous initiatives[2] led by the private sector, research or civil society.

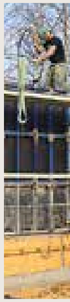
1 Ministry of Culture, Ministry of the Ecological Transition, Ministry of European and Foreign Affairs, to mention just a few

2 Cycle Terre, ECVET, H2020 project, “Africa and Europe: BioClimatic buildings for the 21st Century” (ABC21), etc.

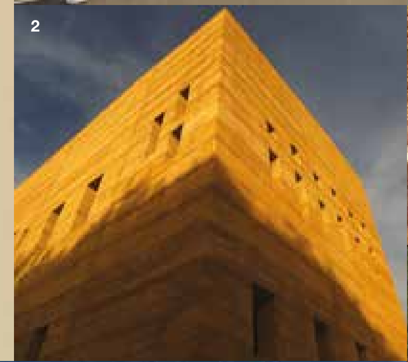
FOCUS

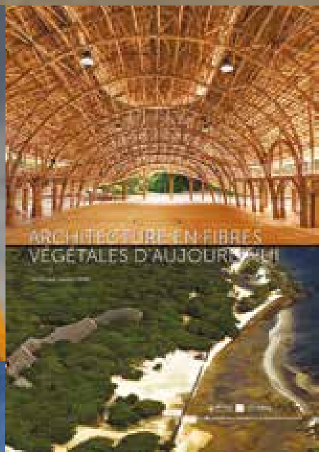
A GLOBAL TREND AND A HOST OF INITIATIVES AROUND EARTH, FIBRES, BAMBOO, WOOD, ETC.

networks of professionals,
research laboratories,
exhibitions,
conferences,
architecture awards,
contemporary architectures and
outstanding buildings
public buildings,
housing programmes,
publications,
theses,
academic teaching,
professional training,
institutional frameworks for development
of sectors
standardisation,
etc.

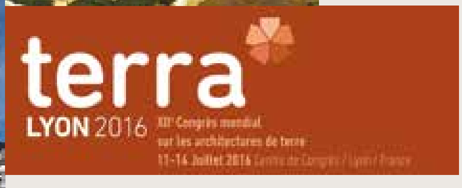


TERRA
Award





TERRA
FIBRA
AWARD



ECVET Earth building

1. European Soil Sample Conservatory -INRAE Val de Loire; Architects: D&A and NAMA architecture
2. College de Paiamboué, Koné, New Caledonia; Architects: André Berthier, Joseph Frassanito, Espaces Libres (K'ADH)
3. "Françoise-Hélène Jourda" office building in Nantes. Architect: forma6 Nantes.
4. Tåkern Visitor Centre Architect: Wingårdhs

1

3

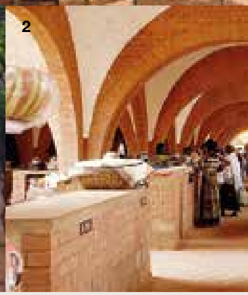
4

1 & 2. Central market, Koudougou, Burkina Faso. Architect: Laurent Séchaud
3. Children's Surgical Hospital, Entebbe, Uganda. Architect: RPBW (Renzo Piano Building Workshop)
4. Justice and Peace Commission, Ouga-dougou, Burkina Faso. Architect: Sayouba Tiemtoré

CULTURES CONSTRUCTIVES
AFRICAINES EN TERRE CRUE
AFRICAN CONSTRUCTIVE
CULTURES IN EARTH

ENAM
École Nationale d'Architecture Marrakech
المدرسة الوطنية للهندسة المعمارية مراكش

2



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INITIATIVES ON THE AFRICAN CONTINENT

networks of professionals,
university programmes,
research programmes
exhibitions,
festivals,
conferences,
architecture awards,
entrepreneurs,
outstanding architects and buildings
publications,
regulatory frameworks,
state social housing programmes
etc.
Mainly concerning earth,
but also fibres, stone, wood, etc.

RENEWAL AND RECOGNITION ON THE AFRICAN CONTINENT

In Africa, this knowledge of local materials and the associated know-how can be observed in various initiatives. Numerous projects are emerging again, led by public or private contracting authorities very familiar with raw earth or fibres, thanks to increasingly competent project management. In parallel with this, NGOs such as La Voute Nubienne promote raw earth masonry and roofing, and big industrial or construction companies, such as LafargeHolcim with their 14Trees project, have invested in the launch of CEB sectors. These initiatives are led by both the public and the private sectors or by civil society, and are integrated in housing, public infrastructure, tourism or commercial projects incorporating a social, cultural or environmental approach, often all three at once. An increasing number of architecture and engineering schools on the continent incorporate local materials in their teaching programmes. Professional training programmes are enriched in the same way and “green” entrepreneurship is developing. Networks of players are emerging. Research is developing and conferences are organised around questions linked to local materials, vernacular knowledge, sustainable architecture and the circular economy, etc. Lastly, regulatory frameworks are beginning to change to adapt to and integrate these practices sometimes overseen by public policies committed to sustainable construction.

Although obstacles remain and there is still some way to go, local building materials enjoy better recognition today. The context is now more favourable for their development through taking into account and better management of local resources. This can be observed to various degrees across the whole continent. We are now witnessing the beginnings of the constitution of a genuine ecosystem, which is developing in proportion to a growing demand and market. However, these developments remain fragile and still too isolated. Supporting and assisting the emergence of this ecosystem constitutes a major challenge to obtain sustainable results on a large scale. This requires long-term political commitments and ambitious strategies.

FOCUS

A LOOK BACK ON AN EXEMPLARY LARGE-SCALE DEVELOPMENT PROGRAMME: **FROM EXPERIMENTATION TO THE CEB SECTOR, MAYOTTE: 40 YEARS OF HISTORY**

In 1979, in response to Mayotte's restrictive insular location, a local materials sector mainly based on production of Compressed Earth Blocks (CEB) was set up with several objectives:

- economic: limiting costly imports of materials and creating jobs;
- environmental: avoiding the use of sand from beaches which was threatening the ecological balance of the lagoon;
- social: developing a large-scale programme to eliminate "sub-standard" housing and building public infrastructures (administration, education, health care, etc.).

The Société Immobilière de Mayotte (SIM) and state services used this sector to set up this ambitious building programme. This programme included original thinking on home ownership allowing the participation of the beneficiaries in several forms (materials, labour and financial participation) and the promotion of a host of local players (quarries, brickyards, small businesses, an artisan group and a purchasing cooperative). For this purpose, a major capacity-building programme had also been set up.

This system enabled the production of up to 2,000 housing units per year. In the space of twenty years, more than 18,000 social housing units and nearly 2,000 public buildings were built. This had clearly demonstrated the applicability of the concept of local materials to large-scale programmes and its capacity to generate local economic development.

Paradoxically, at the turn of the millennium, the Mayotte CEB sector ran out of steam. With less institutional support and a strong resurgence of players accustomed to standardised construction solutions, the value chain of the

CEB sector broke down, leading to a shortage of know-how and players.

Today, in the face of the environmental challenges of quarry sand production and in a context of climate emergency, but also economic and social emergency, the qualities of this local sector are being reconsidered. State services are now supporting CEB solutions again and encouraging their use in major school building programmes. They are also supporting the ART. Terre association made up of local professionals, to establish a normative framework for CEB and redevelop skills.

This taking into consideration of the importance of standardisation in Mayotte had already led to a first “product” standard for CEB materials in 2001 (NF XP P13-901). This work was recently taken up again with the preparation, validation and then publication of a type A ATEx (Technical Experimentation Assessment) which now serves as a reference for major ongoing construction projects, including the Lycée des Métiers du Bâtiment in Longoni which comprises more than 30,000 m² of covered floor area.

Mayotte’s CEB built heritage constitutes an exceptional object of study for our knowledge of this technique, having also revealed the excellent behaviour of the buildings during several major natural hazard events: cyclones and earthquakes. Beyond this, however, this programme provides unique feedback concerning the strategies which served to ensure the viability of a large-scale local sector and provide a long-term answer to the problem of housing across a homogeneous territory.

SIM housing units, Mayotte. Architect: Tand’M Architectes

FOCUS

MAYOTTE: 40 YEARS OF HISTORY
KEY ELEMENTS AND LESSONS OF AN ICONIC AND PIONEERING PROJECT

LOCAL MATERALS AND THEIR USES IN MAYOTTE

EARTH: traditional mud-brick or CEB brick today

POZZOLAN: road, CEB brick, etc.

STONE: basalt stone in foundation, wall, facing, floor, etc.

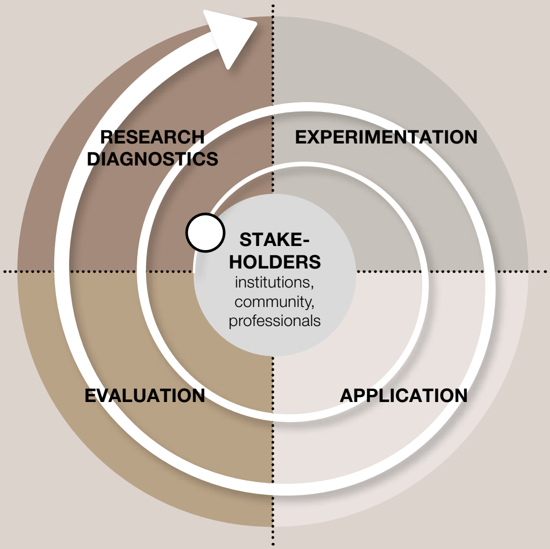
Clearly stated principles from the beginning of the project and consistent objectives supported by the stakeholders which benefited from backing over time:

5 PRINCIPLES

- Participation and empowerment of families
- Non-indebtedness of families
- Ugradability of housing units
- Use of local resources, a factor in employment
- Training of artisans and companies

3 OBJECTIVES

- Respect for traditions and Mayotte culture
- Promotion of local added value through endogenous development
- Exploration of possible alternatives and existing experiences



An effective timescale to produce knowledge for action, through experimentation and innovation at several levels:

1. LOCAL MATERIALS AND THEIR USES

- Use of local resources (earth, stone, wood and plant fibres) with consideration given to the geographical location of the production units
- Development of the associated building systems
- Development of a grouped purchasing cooperative

2. HUMAN RESOURCES AND SOCIAL, CULTURAL AND TERRITORIAL DYNAMICS

- Support for local dynamics and traditional modes of organisation
- Support for family initiatives
- Activation of the artisan base
- Support for business development
- Training and reinforcement of skills at all levels

3. ARCHITECTURAL, SPATIAL AND URBAN

- Taking into account and respecting Mahoran ways of inhabiting
- Support for the emergence of an identity-bearing architecture, adapted to the climatic characteristics and major risks, and on a human scale
- Concerted development of new urban forms and new forms of incremental housing

4. SOCIAL HOUSING

- Implementation of an ambitious and proactive policy
- Implementation of innovative approaches such as progressive in-kind support, etc.

An iterative approach which has made it possible to test, adjust, select and validate the relevant options to construct a solid project thanks to complementary activities in the course of the stages of development of the project and lead to the setting up of a sector.

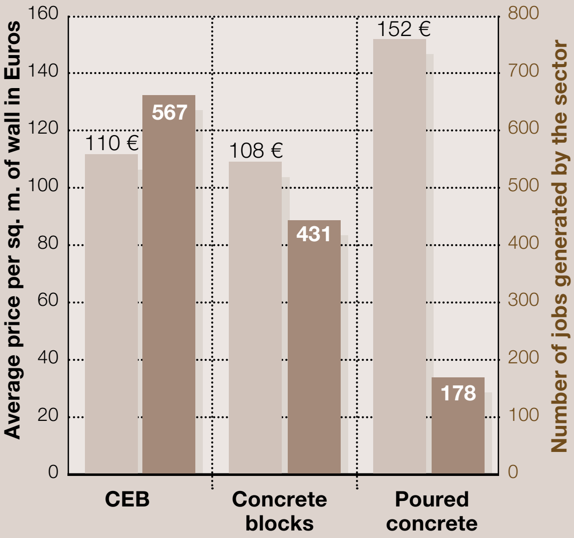
BAMBOO AND RAFFIA: fence or light wall

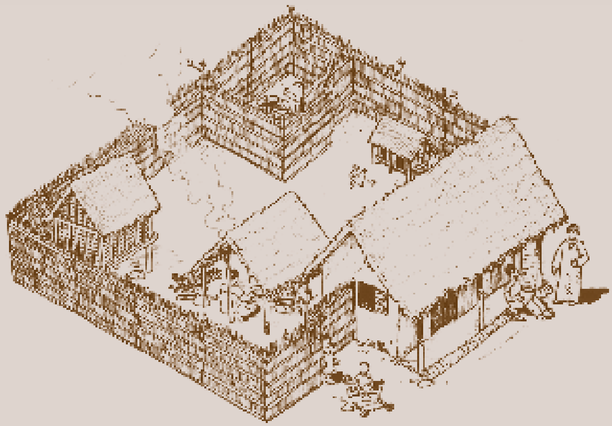
MANGO WOOD: roof shingle

COCONUT: timber, floor, woven palm roof.

Decisive and proven results in terms of environmental, social and economic impact:
Between 1979 and 2001, Société Immobilière de Mayotte built 37 % of all the housing built on the island. More than one in every three housing units and nearly one in every four if we consider all the housing built during this period was built in CEB.

A square metre of CEB wall which is at first sight more expensive, but a much lower final cost for society:
The average price of a square metre of CEB wall in Mayotte is 2.2 % more expensive than coated concrete block wall. The main reason for the "extra cost" is the labour cost which is 25 % higher. The additional jobs generated do not, however, appear in this direct cost and the estimate of the "social" benefit of these jobs economically favours the earth sector by about 1.1 million Euros between 1979 and 2001.





The Shanza, the traditional two-room house and its courtyard, was the subject of a study on Mahoran housing cultures at the beginning of the programme in order to respect these cultures as far as possible in new social housing models.

An efficient job creation cost
Conversely, the cost of creation of a job in the CEB sector is in this project **3 % lower** than that of the cement block sector excluding the social cost. This aspect is often neglected even though employability is a core issue in sustainable development.

Type of wall	CEB 14 cm	Concrete blocks and coating 15 cm
Embodied energy		
in MJ	**37.7**	**363**
Comparative value	**1**	**9.63**
CO_2 content		
kg eq. of CO_2	**3.2**	**56**
Comparative value	**1**	**17.5**

A major environmental benefit
An environmental impact which is reflected by**a ratio of approximately 1 to 10 in favour of CEB** as regards embodied energy and **1 to 17.5** as regards carbon dioxide emissions

2

TYPOLOGY OF RESOURCES ON AFRICAN TERRITORIES

The African continent is rich in many natural resources which can be used for construction. Earth(s), stones, sands, woods, fibres, etc. are resources which are quite widely available, albeit heterogeneously, given the variety of the geographical, geological and climatic contexts. They are therefore exploitable in different ways, especially as the intrinsic qualities of each of them also vary according to the specific characteristics of each territory.

This physical diversity is combined with considerable cultural diversity. This results in a mosaic of situations, including within a given country, which has led to a great wealth of traditional building cultures. While continuity still exists for some of these traditional uses, some of these resources have been the subject of studies and proposals for improvement. Feedback over the past few decades in this field highlights the fact that the potential for large-scale use depends, however, not only on the supply conditions but also on the local capacities to implement them, both from the technical and the economic point of view. It is also a matter of finding solutions which match the means and expectations of the populations concerned in terms of improvement of their habitat (use and value).

Before embarking on projects involving use of these local materials, it is therefore important to have a good qualitative and quantitative evaluation of the natural resources available, and also to take into account the human resources able to use them. This includes the systems of players and skills — existing or necessary — to ensure supply and sustainable and judicious use.

A diagnostic phase is to be encouraged in order to clearly identify the existing potential on a given territory and thus meet needs in an effective and sustainable way. For this, good knowledge of local building cultures — including ways of living but also of management and supply — is a necessary prerequisite for any type of project.

Indeed, many trades based on traditional knowledge of ecosystem management, resource extraction and use of local materials present high potential for updating and revitalisation. There are also many local recipes for additives enabling improvement of the basic raw materials: through-treatments, surface treatments, paints, etc. This traditional know-how and these traditional recipes are also an important source of innovation for the creation of “new”, environmentally friendly concretes, mortars or anti-parasite treatments.

Lastly, it should be noted that appropriateness for a region must today take into account the options offered by transporting of materials “from outside”, especially when their use is relevant and effectively complements what can be done with local materials. Such contributions can also be made temporarily when strategies are set up to (re)create supply conditions in the region itself.

RAW EARTH

Used for millennia for building, raw earth is now appreciated again for contemporary construction: proximity of the raw material, valorisation of know-how, low energy consumption, interior comfort, circular economy, etc.

There are a wide variety of techniques and uses involving raw earth as a structural material (rammed earth, adobe, CEB, etc.), as a filling material (wattle-and-daub) or as a coating on an earthen or other support.

Raw earth in all its forms is still predominantly used informally all over the African continent, and yet it faces many obstacles in terms of being recognised and developing: a negative image, a lack of training courses for building professionals, and a lack of regulations or regulatory restrictions.

NIORO du RIP Professional Training Centre/ Senegal
Architect: KHôZé. Company: #ELEMENTERRE

CHARACTERISTICS

Availability : Abundantly available, on the spot or nearby, or obtained from quarry waste or excavated earth, particularly in urban areas.
Extraction: Little conflict with other interests or impact in terms of land use. Good management is necessary to avoid certain impacts (erosion, landslides, dangerous and unsanitary pits).
Circularity: Potential for use of excavated earth and quarry waste. Non-stabilised, it is a material which is easily reusable and endlessly recyclable or which can be returned to agricultural land.
Energy and emissions : Non-stabilised, it is a low carbon and low grey energy material (processing and use) including for mechanised systems.
Interior comfort: Non-toxic material whose thermal inertia and capacity to regulate humidity provide a healthy interior climate and thermal comfort enabling heating or air conditioning needs to be reduced.
Physical characteristics: Non-combustible and rot-proof material, sensitive to water and presenting good compression strength but

WATTLE-AND-DAUB

The wattle-and-daub technique consists in covering a supporting framework of wooden or bamboo posts and rods with fibrous earth. This makes it possible to build extremely quickly with a very limited volume of materials.

not tensile strength. The addition of additives (fibres) or reinforcements improves its tensile capacities, including against earthquakes.
Sociocultural aspects: Potential for preservation and revalorisation of architectural heritages and know-how of great cultural and social value. Potential contribution to better social integration through revalorisation of practices suffering from negative prejudices.
Durability: When well constructed and correctly maintained, earthen buildings prove to have a very long life span.
Economic aspects: Highly variable depending mainly on the addition of industrial materials and labour costs. The cash cost can be very low for a high-quality self-built house.
Aesthetics and flexibility of use : Because of its range of tones, the grain of the material and its diversity and flexibility of use, raw earth offers the possibility of working with a wide variety of shapes, colours and textures.

APPLICATIONS

Earth, consisting of clay and grains in varying proportions, allows for a wide diversity of applications depending on its composition, hydrous state and mode of use.

- Earth compacted in the humid state (rammed earth, CEB), stacked or moulded in the plastic state (cob, adobe), mixed or applied in the viscous state (wattle-and-daub, mortar, coatings).
- Structural application (walls, pillars, arches, vaults, domes) in monolithic form (cob, rammed earth) or masonry form (adobe, CEB).
- Non-structural application: filling for wall, floor or roof, mortar, covering for facade, roof or floor.

Raw earth complements other natural materials (stone, wood and fibres) very well in various ways.

SUSTAINABLE CONDITIONS OF USE

Evaluation of the type of earth makes it possible to determine its appropriateness for the envisaged use and the need for additives (sand and straw).
Earth is sensitive to driving rain and infiltration of moisture. Good architecture, appropriate construction measures and correct use will ensure good protection. Examples of construction measures: long roof overhangs, substructures and capillary barrier, wear mass or raised platform, protective lime or earth coatings.

ADOBE OR MOULDED EARTH BRICK (MEB)

Adobe is a raw earth brick moulded and dried in the open air. Sand and/or straw is sometimes added to clayey earth. This is the most popular and widespread technique in the world.

RAMMED EARTH

Monolithic rammed earth walls are raised by compacting earth in formwork with manual or pneumatic rammers. This technique is widespread in Europe, China and North Africa, but is developing elsewhere in the world.

COB

Cob walls, very widespread in Africa, are earth walls shaped by hand in successive layers. Their thickness can vary from 5 to 60 cm depending on the use and the presence or not of fibres in the earth.

COMPRESSED EARTH BLOCK (CEB)

The CEB is made of earth compressed with manual or mechanised presses. It is generally stabilised with approximately 6 % cement. This technique was introduced from the 1950 onwards, under affordable housing programmes.

NATURAL STONE

Stone as a building material has long been used as a structural masonry element. Its variable availability depending on the region and the extraction and cutting difficulties it sometimes presents has led it to be reserved mostly for prestigious buildings or monuments. Today, modern means have facilitated its extraction and cutting.

The diversity of the geological formations from which it is obtained is naturally reflected by a wide variety of stones with distinct characteristics (granite, limestone, sandstone, slate, volcanic stone, marble, laterite, etc.). Stone architectures play with structural elements of walls and pillars, as well as in filling or covering.

**Kilwa Tourist Information Centre, Tanzania.
Architect: NAMA architecture**

CHARACTERISTICS

As a geo-sourced material, stone possesses very similar characteristics to earth (circularity, low energy consumption, interior comfort, etc.).

Availability: Material available in quantity in numerous regions, particularly mountainous regions. Certain regions may be located quite a long way away from a good quality stone quarry. Laterite, commonly found in the Sahel, supplies the cut laterite block (CLB) used in masonry.

Extraction: The stones are generally extracted from quarries, but can also come from rivers (river stones). Good quarry management is essential. Transporting of stone can affect rural roads. Stone can also come from field clearance or excavation work.

Circularity: Potential for use of field waste and excavation stones. It is a commonly reused and endlessly reusable material.

Energy and emissions: If the stone is extracted nearby, it is a low carbon and low grey energy material (extraction, processing and use).

Various uses of cut stones are illustrated here: as paving, as a foundation wall, as a substructure, as a squared rubble wall, as a reinforcement in the form of a quoin.

Interior comfort: Thermal inertia and non-toxicity ensure a healthy interior climate and good thermal comfort.
Physical characteristics: Depending on the type of rock, a material which can be very robust, durable over time and little affected by humidity. Stone masonry elements have high compression strength and low tensile strength. They can be sensitive to capillary rise.
Sociocultural aspects: Potential for preservation and revalorisation of architectural heritages and the associated know-how.
Durability: When well constructed and correctly maintained, stone buildings have a very long life span.
Economic aspects: Highly variable depending on the distance from the quarry, the difficulty of extraction and cutting, the addition of industrial materials and the labour costs.
Aesthetics and flexibility of use: A generally appreciated material, which evokes the image of prestigious monuments. Stone presents an extensive range of possible colours, textures and shapes. Its use is however less flexible than other ecomaterials.

APPLICATIONS

Stone offers various products and applications in construction which depend on the properties of the rock (hardness and resistance to attacks):

- Used in the form of a cut block or lauze (flat stone) or in an irregular form, i.e. “as-dug”.
- In structural application: foundations, walls, pillars, lintels, arches, vaults, domes, staircases, etc.
- In non-structural application: filling of walls, covering of facade, roof and floors.

Use of stone is very appropriate as a complement to earthen walls (foundations, lintels, window sills, projecting corners, posts, under framing members to distribute the load, as a reinforcement for walls, etc.).

SUSTAINABLE CONDITIONS OF USE

Stone masonry requires highly qualified know-how for cutting and bonding. It may or may not use mortar (earth, lime or cement) The mortar serves to fill the voids and wedge the stones, but it does not act as a “glue”. Stability is ensured by correct positioning of the stones.
Stone masonry can be sensitive to capillary rise; suitable architectural and construction measures will ensure good protection.
Dry stone masonry (without mortar) allows certain animals to nest (birds and lizards), which limits the presence of harmful insects (mosquitoes).

TIMBER

Wood is highly valued for its aesthetic qualities, its lightness, its strength and its ease of use in light-frame buildings. Wood is still commonly used on the African continent, whether supplied by the informal artisanal sector or by the industrial sector, but timber production is rarely managed sustainably. In addition, many current practices in Africa (unsuitable drying, speed of execution, etc.) contribute to giving wood a negative image, especially as the best wood is exported out of the continent. It tends to be replaced by imported materials (steel and PVC for joinery).

As a bio-based material, wood presents several major advantages which make it a material of choice for green construction, if it is managed sustainably. Over the last few years it has become a powerful lever for changes in building techniques, architectural renewal and economic development. It is frequently recognised by standards and faces fewer regulatory obstacles than most other bio-based or geo-sourced materials.

STRUCTURAL BAMBOO

Structural bamboo is seen as an effective alternative to timber because of its growth rate, mechanical strength and environmental qualities. It can be used in the same way as wood for frame or roof structure.

Despite certain initiatives, its structural use is uncommon in Africa, it being used more as wattle in wattle-and-daub, in the secondary structure (walls and frame), as a wall covering or in the form of tiles.

The introduction and promotion of structural bamboo for construction in Africa would be worthwhile, but requires the creation of the sector from scratch, including the introduction of new skills.

CHARACTERISTICS

Availability: Forest covers 22 % of African land, mostly in the tropical region. 75 % of these forests do not have a sustainable management plan and deforestation is accelerating. Mangroves are even more threatened. Currently, the available resource is therefore limited. Certain regions, such as the Sahel, have practically no access to it.
Extraction: A renewable resource, but seldom renewed in Africa. Over-exploitation has a negative impact on the environment (biodiversity, soil stability, climate change and water resources). Otherwise, responsible exploitation has a very positive impact.
Energy and emissions: Potential carbon sink if the forest is managed sustainably. Conversely, the carbon footprint is very unfavourable. The energy (and carbon footprint) intrinsic to its production varies according to certain factors (transport, industrial processes and treatments).
Circularity: Biodegradable material which easily allows reuse and recycling (without toxic treatment). Production waste can be recycled.
Interior comfort: A breathable and insulating material, it contributes to ambient comfort and a healthy climate (without harmful treatment). It has a low thermal inertia.
Physical characteristics: A material with

very beneficial properties: tensile and bending strength, light. Wood provides appropriate solutions in areas subject to earthquakes and cyclones. Depending on the essence, a material sensitive to humidity, fungi and insects. A fire-propagating material, but presenting slow combustion and fire stability, enabling damage to be delayed.

Durability: Highly variable depending on the essence of the wood and the attention paid throughout the life cycle of the building (from felling to maintenance). Wood elements have a potentially very long life span and are easy to repair or replace.

Sociocultural aspects: Numerous communities depend on the forest for their survival and their income. Access to quality wood often determines the ability of populations to have adequate and affordable housing. Promotion of the wood sector is simultaneously highly beneficial for the environment, the well-being of many populations, local economies, cultural heritage and access to housing.

Economic aspects: Costs highly variable depending on the wood essence, the transport, the industrial processes and the treatments. Quick-to-use material Gain in floor area (walls less thick than in masonry).

Aesthetics and flexibility of use: light, flexible, strong and easy to work, wood offers a great wealth of uses and architectural expressions. The framing system is very flexible and easy to convert and extend.

APPLICATIONS

Wood offers a great variety of products and uses:

- Solid wood (rough or planed; round, squared or sawn) or engineered wood (glue-laminated, reconstituted, plywood, I-beam, etc.)
- In structural application: foundations, walls (post-and-beam, framework or stacking), pillars, beams, lintels, staircases, floors, roof frame.
- In non-structural application: joinery, coverings (wall, ceiling, floor, roof).

In vernacular architecture and in green construction, wood is often combined with other geo-sourced and bio-based materials, particularly for wood frame structures.

Wood lends itself to self-building, prefabrication and craft trades as well as to industry. Wood allows rapid implementation. It does however require a minimum amount of know-how, or even highly qualified know-how depending on the techniques, particularly in regions subject to earthquakes or cyclones. The methods of assembly are numerous and can be adapted to all situations.

Wood can be used in a host of ways: for structural work (supporting structure, walls, floors and frame) or for non-structural work (light walls, joinery or covering of floors, walls and ceilings). Above: Nakuru Project, Kenya. Architect: Orkidstudio

SUSTAINABLE CONDITIONS OF USE

Deforestation is a major issue and **sustainable exploitation of wood** is essential (resource renewal, judicious felling and diversity of essences) combined with support for the development of the sector.

To **increase the life span of wood**, various practices are to be encouraged **throughout the building's construction and life cycle**: felling (season, maturity); drying; constructive and architectural measures; choice of essences and selection of timber pieces; treatments and finishes; maintenance. A lot of traditional knowledge and know-how deserves to be studied and promoted.

Certain chemical treatments (insecticides and fungicides) must be used sparingly because they can generate health and environmental risks and limit the recycling of wood.

NATURAL FIBRES:

Natural fibre-based materials, or bio-based materials, are materials partially or totally obtained from biomass of plant or animal origin, such as wood (timber and derived products), bamboo, palms, thatch (reeds, grasses or straw) and other natural fibres (sisal).

Hundreds of plant species are widely used in the world mainly for roofs, but also for walls, floors and secondary elements (ropes and mats). Innovative materials complement the wide range of products and applications: insulators (wools, straw bales, etc.), mortars and concretes (earth-straw mixture, etc.), panels or uses in building chemistry (glues, additives, paints, etc.).

These plant materials offer very appropriate solutions and constitute a tremendous opportunity to limit greenhouse gas emissions and store a large quantity of carbon.

Typha Craft Centre, Maka Diama, Senegal.
Architect: Atelier Migrateur Architecture

CHARACTERISTICS

Availability: Bio-based materials of plant origin — excluding wood — are available, or potentially available, in all regions, including in arid areas. Numerous naturally occurring and cultivated species are available in Africa (various grasses, typha, bamboo, reeds, cereal straws, palm leaves and sisal).

Extraction: A renewable material, obtained from fast-growing plants from three types of sources: naturally growing vegetation, agricultural by-products or specifically cultivated crops. Their cultivation only requires a small amount of water and inputs. It has the advantage of stabilising soils and being able to preserve (or restore) natural ecosystems.

Energy and emissions: The grey energy for production is generally low or even nil. The carbon footprint is very favourable thanks to carbon storage.

Circularity: These materials are untreated and can be easily reused or recycled, or are biodegradable. Certain materials are obtained from the recycling of waste or by-products.

Interior comfort: Materials possessing good thermal and sound insulation properties. Depending on their use, they allow ventilation, filtering of light or good interior air quality (perspiring and healthy).

Physical characteristics: Highly variable depending on the plants and the conditions

of use. Materials generally presenting good tensile performance with a good strength-to-weight ratio. Potentially combustible, sensitive to biological agents, humidity and attacks and presenting low resistance to compression. By tightening or compressing the fibres or embedding them in mortar, these drawbacks can be considerably reduced. They can provide good structural performances and help to reduce risks (damage and injuries) in the event of earthquakes and high winds.

Sociocultural aspects: Numerous traditional practices exist, based on a threefold heritage of *land management, craftsmanship and architecture*. They are faced with prejudices and a process of abandonment. Their renewed promotion therefore presents great potential both for the environment and for the local economy and cultural heritage.

Durability: The durability of elements obtained from plant matter is highly variable and depends on the type of plant, the use, the quality of implementation or the use of treatment. A palm roof lasts 3 to 10 years whereas a high-quality, well-maintained thatched roof has a life expectancy of more than 30 years.

Economic aspects: Extremely variable costs. The raw material is generally cheap or even free. Its level of artisanal or industrial processing affects its costs to varying degrees. Numerous traditional applications may thus

require no cash, whereas industrialised wall panels made of natural fibres are more or less at the same cost as conventional materials.

Aesthetics and flexibility of use: Plant fibres have very high aesthetic potential. They offer great flexibility of use and unlimited architectural and artistic expressions.

APPLICATIONS

The functions which plant materials may serve in construction are highly varied:

- fibres, grasses or leaves can be twisted, interwoven, bundled or compressed to carry, reinforce (strengthen or fibre-reinforce), bind, encase, isolate, filter (sunlight or air), protect (cover), decorate, etc.
- they provide a variety of products for roofing, covering of walls and ceilings, insulation, mortars and concretes, substructure for wattle-and-daub, tying (ropes), filtering light or ventilating (screen walls) or for use in building chemistry (glues, additives, paints, etc.).

In Africa, the most common traditional and contemporary uses of plant fibres are to cover thatched roofs (reeds and straw) or palm roofs, to strengthen and fibre-reinforce clayey earth (bricks, wattle-and-daub, cob and rammed earth, coatings) and to produce ropes and mats.

In industrialised countries, one emerging market is that of bio-based insulators. Experiments are also being conducted in Senegal with typha.

SUSTAINABLE CONDITIONS OF USE

The use of cultivated plant materials must not contribute to conversion of natural ecosystems, deforestation or forest degradation and must not compete with food crops.

Extraction of naturally occurring species must also be judicious and comply with certain good cutting practices to enable renewal, maintain ground cover and preserve the ecosystems they accommodate, particularly in humid areas.

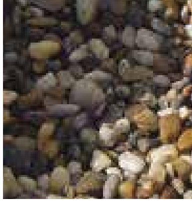
Identification and characterisation of the plant species traditionally used in a region is an essential step.

The life span of the elements depends on compliance with good practices for cultivation, selection, cutting, transformation, implementation and maintenance. Similarly, depending on the species selected and the way they are used, particularly the level of compression of the fibres, the combustibility of the elements can be considerably reduced.

Certain chemical treatments (fireproofing treatments, insecticides and fungicides) exist, but their cost is often high and their use can generate health and environmental risks while limiting recycling.

We are seeing a renewal of the traditional use of plants fibres in construction: roof thatch, light walls, etc.

BINDERS: PLASTER, LIME, CEMENT



Plaster, lime and cement are mineral binders used in various places in buildings, mainly for mortars, concretes and coatings. Their use, particularly that of cement, has become almost indispensable.

Energy and emissions: These binders are obtained by combustion of rocks (gypsum, limestone and clay). Their production generates GHG emissions, particularly for cement (firing at 1450 °C) and lime (firing at 900 to 1250 °C). Plaster, fired at less than 200 °C, has a lesser impact and also presents the advantage of being recyclable.

Availability: Production sectors exist in Africa on a larger or smaller scale and mainly on an industrial scale. The cement sector is overwhelmingly predominant. However, despite the strong increase in production capacities across the continent, more than 60 % of African countries import between 50 % and 100 % of the cement consumed, from neighbouring countries or from Europe or Asia. Furthermore, the price of cement is much higher in Africa than elsewhere (in 2014, a 50 kg bag cost on average $9.57 compared to $3.25 in the rest of the world) (World Bank, 2016).

Plaster production sectors are mostly located in North Africa. As regards lime, there are industrial production units in several countries in Africa (particularly in North Africa but also in Nigeria, South Africa, Sudan, etc.). Artisanal production sectors also exist in various places on the continent.

Characteristics: Plaster and lime are materials which allow a healthy interior climate because they breathe and regulate humidity. They adapt very well on earthen or stone supports or can be combined very successfully with plant fibres. Cement, for its part, is not a good hygrothermal regulator and can stop the support from breathing (depending on its dosage).

APPLICATIONS

Plaster is more often used indoors: mortar, mouldings, coatings, wall panels and masonry elements. Lime is used indoors and outdoors: mortar, whitewashes and paints, foundation concrete. Cement has a very wide field of use at all points of the building, in the form of concrete (reinforced or cyclopean), mortar, prefabricated elements or coatings.

SUSTAINABLE CONDITIONS OF USE

The negative environmental impact of these materials, particularly of the cement industry, is encouraging the development of two types of strategies:

- reduction of GHG emissions in production (development of low carbon cements), and
- reduction of their use to the strict minimum necessary through intelligent design of buildings and complementary use of materials with a lower environmental impact.



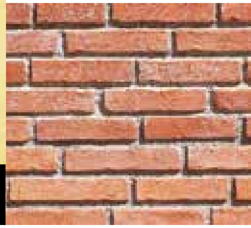
SANDS AND GRAVELS

Sands and gravels are the most widely consumed resources after water, more than half being used by the building industry. Their massive and often poorly managed extraction has a major impact on the environment (coastal and marine ecosystems, biodiversity, soil erosion and degradation, lowering of the water table, etc.) and on certain economies (tourism and fishing).

Unsuitable sands are sometimes used in construction, compromising the quality and durability of concrete.

High-quality sand is becoming a rare commodity and this leads to illegal exploitation and the rising power of "sand mafias".
Several strategies have been identified to confront these huge challenges, including:

- reduction of sand consumption through the use of alternative materials;
- implementation of regulatory strategies for procurement of aggregates.



TERRACOTTA

Terracotta bricks are obtained by firing clayey adobe bricks. Their main advantage compared to adobe (raw brick) is their high resistance to humidity.

They are very widespread in Central Africa, East Africa and Southern Africa. However, the massive deforestation caused by their firing is encouraging moves to other materials such CEB or sand-cement blocks. Certain artisanal brickworks demonstrate remarkable knowledge in the control of firing, comparable to that of potters, but this not always the case.

This material is currently criticised due to the increasing shortage of wood and the atmospheric pollution caused by firing. An effective means of reducing this negative environmental impact is to use these fired bricks for the exposed parts of buildings such as the foundations, substructures, corners, wall ties, etc. and to fill in the rest of the masonry with unfired bricks in the same format. Such an approach is already found in certain building cultures (Madagascar).

FOCUS

BUILDING WITH LOCAL MATERIALS

Building with local materials means:

- Having a good knowledge of the geological and soil resources and the biomass of the territory on which one is building.
- Using these resources for the construction of human settlements in a sustainable, economical and intelligent way.
- Controlling the process by which to transform this raw material into an element or a component and combine it with others to make a sustainable building with them to satisfy needs.
- Benefiting from and making good use of the empirical knowledge developed by the builders who came before us and who in most cases passed on this knowledge through apprenticeship and on building sites.
- Respecting principles and construction measures which will make materials often deemed “fragile” or “non-durable” into constituents of buildings which will stand the test of time.
- Knowing how to maintain, repair and modify these buildings to adapt them to new uses and needs, including in urban areas.
- Being capable of thinking “life cycle” and “short production chain” by way of the local materials available in order to reduce the impact on climate change.

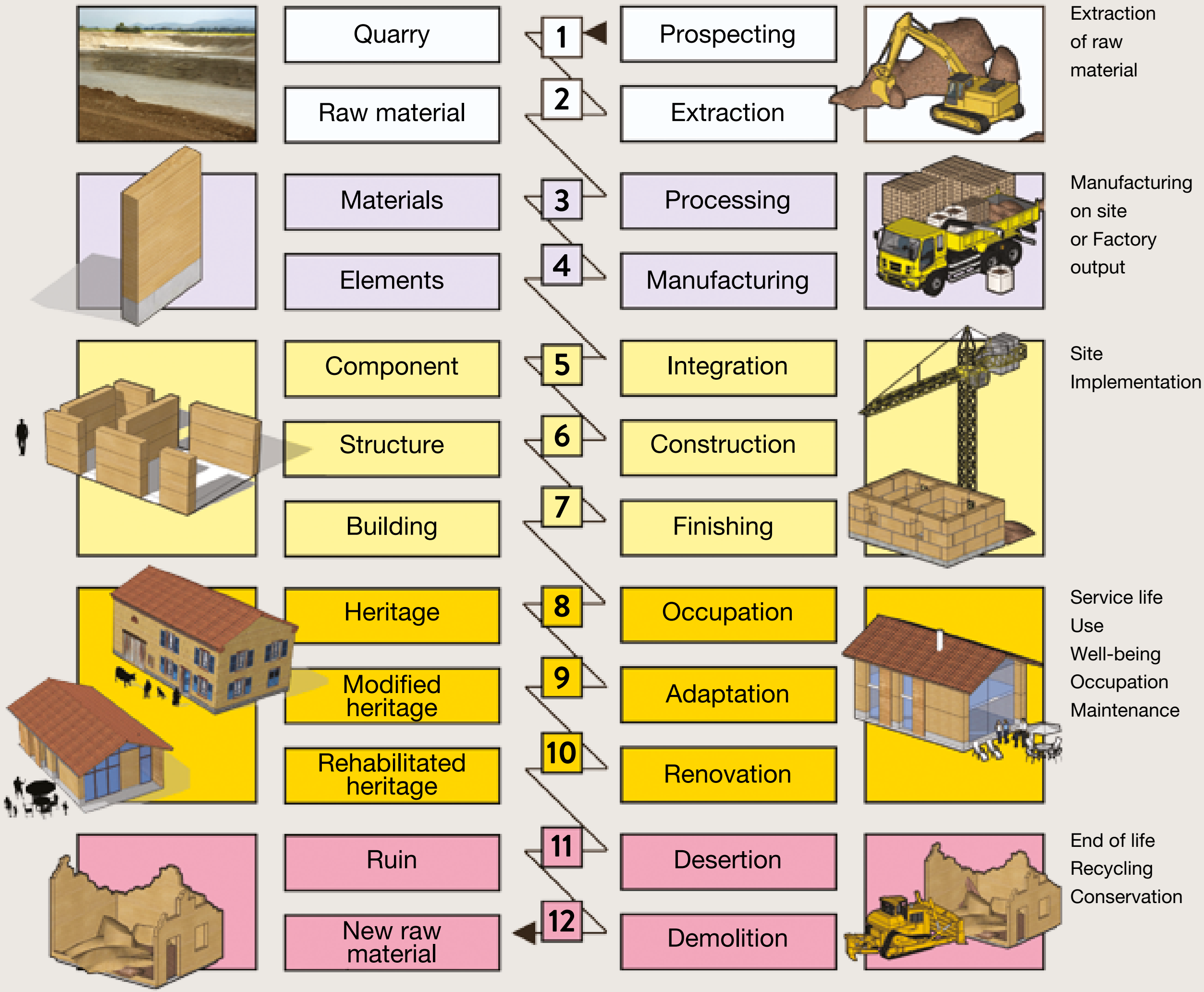
The guiding principles for building with local materials are no more complex or simple than for other materials. It is necessary above all to use them wisely and to comply with certain rules which are sometimes not specific. This could be summarised as follows:

- Checking the correct siting of the building to make the most of its exposure to sunlight, reduce potentially unfavourable exposure (to rain and wind) and take into account the natural hazards to which it might be subject (earthquakes, landslides, flooding, unstable terrain, etc.).
- Ensuring the solidity and stability of the building through a construction system, foundations, substructure and peripheral wall ties which are correctly sized, which are adapted to the characteristics of the structure, the geotechnical nature of the sub-soil and the topography of the terrain and which, when necessary, incorporate additional construction measures to combat natural disasters (earthquakes, cyclones, avalanches, etc.).
- Protecting the building against damp problems due to capillary rise, stagnant water or infiltrations by keeping walls clear of water (earthwork, substructure, capillary barrier, breathing coating, roof with overhang, etc.) and managing rainwater (guttering, rainwater spouts, drains, etc.) so that it is drained off without affecting the structure or the area around it.
- Using other materials, reinforcements or “sacrificial” or wear systems to reinforce the parts of buildings subject to specific stresses (corners of walls, door and window frames, parapets, terraces, etc.).
- Ensuring good anchoring of floors and the roof frame system, particularly for the latter when the area is exposed to violent and extreme storms or winds.
- Providing expansion joints in the case of construction in an urban area or when the dimensions are large, to avoid problems due to differential settlement or to expansion/contraction or swelling/shrinkage phenomena.
- Guaranteeing optimum integration of the construction in the natural environment and the surrounding built heritage and searching for solutions which contribute to adaptation to climate change.

LIFE CYCLE
FROM THE QUARRY TO RECYCLING

STATE OF THE MATERIAL

PHASES OF IMPLEMENTATION



Plant fibres are once again playing a key role in the production of new contemporary architectures. Potential uses reinterpreting traditional heritage are increasingly being devised.
1. THREAD Artists' Residence and Cultural Centre, Sinthian, Senegal architect: Toshiko Mori Architect
2. "Living Tebogo", home for handicapped children, South Africa, by BASEhabitat

3

MEETING TODAY'S BIG CHALLENGES: THE POTENTIAL OF LOCAL BUILDING MATERIALS

AFFORDABLE HOUSING
Local materials present a tremendous opportunity to meet the continent's growing needs for suitable, decent and sustainable housing through strategies of support for local initiatives and developments enabling better use of resources, knowledge and jobs together with savings and adaptation to climate change.

SOCIOECONOMIC IMPACTS
Strategies based on the use of local building materials have the potential to strengthen national and regional economies while reducing their dependency in the face of global variabilities, to revitalise the socioeconomic fabric of regions and create lasting jobs and vectors for cultural and social enrichment.

ENVIRONMENTAL IMPACT AND CLIMATE CHANGES
The use of local building materials supplied and produced in a sustainable way has the potential to reduce pressure on global resources and ecosystems and to preserve the environment and local resources through their valorisation and correct management. It has the potential to attenuate the effects of climate changes by reducing the use of imported and high carbon materials and enabling the adoption of construction systems which reduce energy needs.

HEALTH AND WELL-BEING
The habitat is an essential element of everyone's well-being and health. Building with healthy materials which do not produce or give off pollutants is essential. This goal can be achieved through the use of materials which must be implemented in architectures which contribute to the well-being of populations by providing spaces adapted to local needs, practices and uses.

RESILIENT BUILT ENVIRONMENT
Frequently perceived as being fragile and non-durable, local architectures and building cultures are often the result of an adaptation to the environment in which they are built, constituting models of resilience from which our contemporary societies are starting to draw more and more inspiration. Local materials envisaged as a simple consumer product are perishable. As the result of a process, however they can provide an answer to global challenges.

CULTURAL IDENTITY AND MODERNITY
The promotion of local building materials and the building cultures which are associated with them has the potential to preserve architectural and landscape heritages, to highlight the diversity of local knowledge and know-how and to facilitate the emergence of new sustainable and contemporary architectures drawing on vernacular genius.

MEETING THE CHALLENGES OF CONTEMPORARY HOUSING

Since the 1960s, national housing policies in Africa have alternated between different approaches described as the "state" approach, the "economic" approach, the "enabling"[1] approach, the "private sector delegation" approach, etc., including in the Global Strategy for Shelter promoted by the United Nations in 1988, which aimed for "housing for all in the year 2000". Despite the progress made, the results were unfortunately far from reaching a satisfactory level. The shortage of decent housing increased in most countries and, furthermore, the issue took a back seat compared to other priorities.

After nearly two decades of being almost "asleep", most African countries are faced with a major housing crisis, both quantitatively and qualitatively. The shortage stands at more than 50 millions units (Bah et al., 2018), and is continuing to get worse. In response to the continent's high demographic growth and its steady urban transition, approximately 160 million additional units will have to be built between now and 2050 (approximately 20,000 homes per day), and this is if existing homes are renovated or adapted to new needs. Beyond these figures, it is also a matter of designing architectures corresponding to different modes of inhabiting and which better take into account the consequences of climate change.

Today, the majority of households and communities in both rural and urban areas are resorting to "making do", self-building, mutual aid and incremental approaches, implemented with the help of artisans, entrepreneurs or small businesses. This third sector, largely informal and therefore often disparaged, is the continent's leading provider of housing. Expressing itself in a variety of ways according to the specificities of the contexts concerned, it often proves to be very effective for building less expensively, illustrating local capacities for innovation. The building techniques and materials used for this "informal" housing are highly varied: "local", "thermo-industrial", "reused" or "recycled" materials. Very often, the construction systems are heterogeneous or hybrid. In Ouagadougou in 2002, 50 % of the housing was in adobe and 40 % used a combination of adobe and cement blocks (World Bank, 2002).

Given the issues and priorities involved, ambitious social housing programmes must be launched across the continent, necessitating large and costly investments and resources. The standard conventional approaches having shown their limitations in terms of meeting the demand of the poorest (and numerically biggest) population groups, we

1 "Enabling strategies", promoted by the "Global Strategy for Shelter to the year 2000" and by the "UN-Habitat" programme.

Opposite page: Compact housing in informal neighbourhood, Maputo, Mozambique. Architect: Casas Melhoradas

need to avoid staking everything on such exclusively quantitative reasoning backed by a completely "thermo-industrial" approach. These choices have the effect of increasing costs, reducing local economic impacts, impoverishing architectural models, producing unsuitable and uncomfortable living places, generating more pollution and causing the devaluing of local building cultures. Now CEB, for example, one of the best known local materials albeit not one of the most economical solutions, has enabled a cost reduction of around 25 % in many African countries (Bah et al., 2018). Nevertheless, it remains necessary to check this potential in each context and for each project.

It is recommended moreover to the approach the economic issue of housing in an integrated way (land, architecture, mode of production and construction, credit, affordability, etc.) and to identify the specific contribution of local materials in relation to the chosen modes of production and construction and the share they represent in the final cost. The choice of certain modes of production may increase the final cost of the housing and be unaffordable. For example, production of local materials will present different costs and a different breakdown of expenses depending on its organisation, which may be highly industrialised and centralised, or on the contrary "decentralised" in workshops with simple production equipment. It is therefore imperative to think about the sociotechnical modes of organisation associated with local materials if we want to exploit their full potential. We should therefore beware of "copy-and-paste" solutions and try instead to clearly identify and base ourselves on existing developments for which we can propose improvements and adaptations (technical, social, economic, land-related, etc.) in cases in which this is useful or necessary.

The challenge is to envision the change of scale to meet current housing requirements in Africa while at the same time preserving the potential of local materials and of contextualised approaches, which has been able to be demonstrated by certain projects which must be identified and serve as references not only from the technical but also from the methodological point of view.

CITIES AND LOCAL MATERIALS

The use of local materials in an urban environment is often seen as being impossible or even inappropriate. The recurring questions are: how can you do things "locally" in an urban context? Is it possible? Is there any benefit in it?

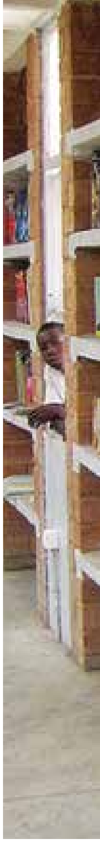
From the beginning of urbanisation, people built by procuring materials from the nearby area for logistic and economic reasons. The great pre-industrial civilisations and societies built their cities using local materials.

Production centres then became concentrated, often on the outskirts of cities or at the places of extraction of the resource. With the industrial era, supply distances became longer, made possible by inexpensive fuel and more effective means of transport. The economies of scale achieved allowed costs to be reduced and enabled this logic to be pushed to the extreme. Long ignored, the effects of this logic have been disastrous for the planet.

Today we are rediscovering the virtues of doing things locally. The past shows us the extent to which building cities, and in cities, with local materials is possible, and that it was already a question then of densification and durability. Today's innovations must allow us to rethink the place of local materials and the benefits this will bring (healthy materials, production sectors, employability, quality, reduction of the carbon footprint of buildings, etc.) for cities and their inhabitants.

The challenge is therefore to think in terms of short production chains and to bring the production of materials closer to the places of construction, notably cities. Cities are still reservoirs of raw materials and/or places of production which need to be evaluated. Although bio-based materials are not necessarily available at first sight in cities, nothing prevents us from imagining being able to produce them in urban areas. As regards geo-sourced materials, subsoils (or surrounding areas) can constitute reserves as is currently the case in the Grand Paris Express project in which excavated earth is used. We need to devise future urban projects with this dimension and envisage any land development strategy with the question of building materials and local production chains in mind. It is not only possible and desirable to count on local materials for cities, but also very appropriate. It is therefore necessary to anticipate, plan and manage this within the framework particularly of SDGs 11 and 12 and their implementation.

EXPLOITING THE SOCIOECONOMIC POTENTIAL OF TERRITORIES



The construction sector in many African countries largely depends on the importing of conventional building materials (or of the energy to produce them) and relies on a limited number of players of sometimes international scope. This generates a twofold cost, economic and environmental, compounded by the high vulnerability of global supply chains to external import variabilities and to growing climate and health risks. In addition, depletion of resources, particularly energy resources, is bound to increasingly affect construction costs, in conjunction with the exponential growth of construction needs.

In response to these challenges, strategies to relocate the production of building materials close to projects, combined with the use of local, renewable or near-inexhaustible and low-energy raw materials, are destined to develop. By reducing dependency on energy and external resources, they have the potential to root capital and investment durably in the region, reduce vulnerabilities to external shocks and provide freedom from global economic variabilities while at the same time enabling a reduction in construction costs.

Beyond these macroeconomic aspects, such relocation processes have the potential to contribute significantly and durably to the socioeconomic revitalisation of regions, because they allow not only the material resources but also the human resources of the region to be used optimally. It is possible to draw on existing knowledge and know-how and exploit sometimes thousand-year-old experience while at the same time supporting the development of new and complementary skills in order to fully meet today's requirements. In addition, by drawing on shared and mastered know-how, we foster family and community participation (mutual aid, exchange and self-building) and therefore social cohesion while at the same time reducing building and maintenance costs.

Lastly, short and local production chains facilitate support for and development of a local, diversified and flexible entrepreneurial fabric rooted in the region. This facilitates local exchanges and cooperation between economic players on the territorial scale and, in the end, generates economic and social added value in the region.

The choice of local materials and modes of production based on a local entrepreneurial network is not incompatible with ambitious quantitative objectives. When the whole building sector is taken into account, it is tremendously effective. Certain examples, as in Mayotte, have already proved the applicability of a local materials approach through support for a host of local players.

Developments linked to local production chains are omnipresent in Africa, both in the urban and in the rural environment. They are generally the product of an informal economy and are based on self-building and on the use of self-employed workers or micro and small businesses. These "small economic units" account in reality for the majority of employment in Africa[1]. However, these developments are still little documented and highlighted and do not benefit from integrated support.

[1] Concerning the industry sector (including construction), in Africa more than 60 % of employment in the industrial sector is accounted for by the informal sector and small economic units (self-employed workers and micro and small businesses) represent more than 80 % of all employment. ILO, 2019.

Katiou Library, Komsilga, Burkina Faso. Architect: Albert Faus

STIMULATING DECENT EMPLOYMENT AND STRENGTHENING LOCAL CAPACITIES

When production of materials is structured on an artisanal or semi-industrial scale, the use of local materials offers considerable potential for creation of qualified and unqualified jobs which cannot be relocated along the whole production–construction–maintenance chain. The ILO indicates that for the same level of investment the use of technologies based on labour could create between two and four times more employment (mainly unqualified) (ILO, 2004).

In addition, according to the ILO (ILO, 2019), decent work is particularly lacking in the informal sector and within the smallest companies, and the construction sector in Africa is particularly subject to this. Apart from the aspects linked to working conditions, it is the image itself of the artisan's work which has progressively deteriorated, in association with the loss of value of traditional know-how, the "monetisation" of building activities and limited economic means, but also with the massive arrival of cement block masonry, which offers a "single model" whose execution is very often characterised by a certain degree of mediocrity, at least in the informal sector.

Strategies for promotion of traditional techniques and highlighting of their genius, as well as those favouring the emergence of innovative architectural production incorporating local materials, are therefore accompanied by technical and vocational training for the various players in the sector, including artisans, engineers and architects. These strategies are a lever for promotion of the artisan's know-how, providing him with economic added value but also with dignity in his work. Training of engineers and architects around this knowledge and the technical and architectural innovation potentials it can inspire is an essential factor for cultural and social enrichment of a region.

CHOICE OF MATERIALS: AN ESSENTIAL LEVER TO MEET ENVIRONMENTAL CHALLENGES

Demographic forecasts leave no doubt: the environmental challenges of the building sector in the decades to come will play out in Africa.

Globally, the building sector is the biggest **contributor to climate change** (39% of GHG emissions), but the African continent's share in emissions is still small. This can be explained by a certain energy "frugality" in the building use phase (heating/cooling, hot water and lighting). In Africa, the sector's emissions are mainly linked to the importing and production of carbon-intensive materials (cement, steel and fired bricks). However, GHG emissions are destined to increase exponentially in the face of the expected construction needs, which defy the imagination, but also in the face of increased demand for cooling of buildings.

The challenges linked to **exploitation of resources** appear even more worrying. On the one hand, non-renewable or non-renewed resources are being depleted, as in the case of wood or sand, an ever rarer commodity which is extracted at an unsustainable rate, leading to the increasing power of "sand mafias". On the other hand, massive and often poorly managed extraction of these resources has disastrous effects on ecosystems: loss of biodiversity, erosion and degradation of coastlines and lands, lowering of water tables, soil salinisation, etc. The economic and social repercussions are considerable, among other things on agricultural productivity, fishing and tourism. This also amplifies the vulnerabilities of African territories to climate change and natural hazards, particularly in coastal areas, where a large proportion of human settlements are located.

KEY FIGURES

24 % of the raw materials extracted from the earth worldwide are used in building activities. (source: GlobalABC)

The building materials industry is responsible for **11 %** of global GHG emissions. (source: IEA)

Global production of cement, the second biggest industrial emitter of GHG with **8 %** of emissions (3 % for the building sector), has increased by 80 % in 10 years and could be tripled by 2050. (source: IEA)

Lastly, **building material waste** which cannot be recycled or reused constitutes another burden for the environment, one which is currently not very visible in Africa but which is destined to increase.

In the face of these huge challenges and in this seemingly insoluble equation, **the choice of building materials and technical systems is a decisive lever**. It is therefore urgent to rationalise the use of resources and reserve cement, sand and fired bricks, which are precious materials, for strictly necessary uses. And to combine them, where appropriate, with building materials supplied sustainably and responsibly and obtained from raw or little-processed materials. In this sense, raw earth, stone, plant fibres and sustainably managed wood present various environmental advantages:

- They are **renewable** or **widely available** across the region and can be **obtained from recycling** (e.g. backfill).
- It is common to find appropriate building materials **close to sites**, or to (re)launch their production in order to **minimise transport**.

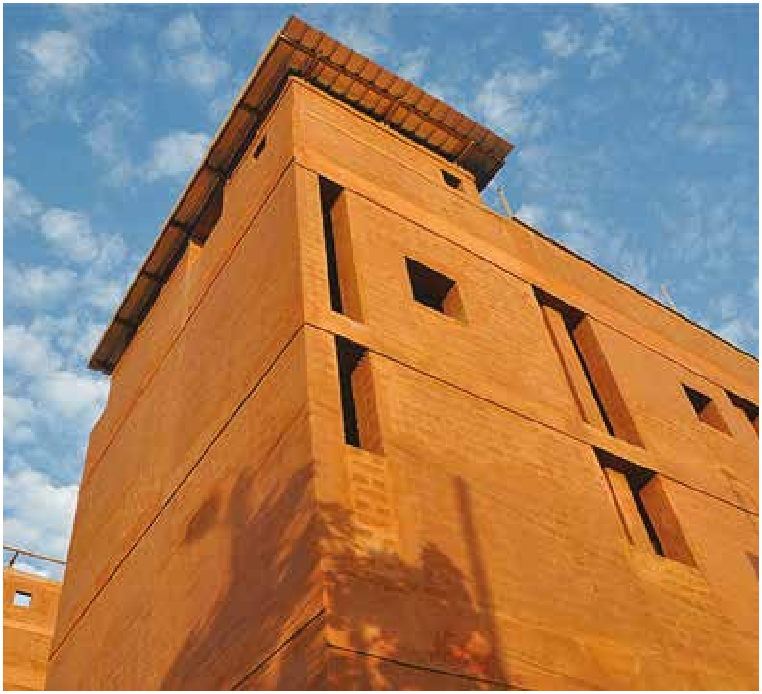
Life cycles of materials: on the left, industrial materials, energy consuming and waste producing, and on the right, local materials, non-industrialised and reversible.

- They **require little or no energy** to be processed or recycled, bio-based materials having the advantage of being able to **store carbon**.
- The varied characteristics of these materials (massive, light, enabling air circulation or humidity control, insulating, etc.) easily allow **use adapted to the various climatic conditions**, in accordance with "passive" design strategies (**bioclimatic architecture**).
- If treated without chemical or stabilisation processes, they are **biodegradable**, **are easily recyclable or allow reuse** and can participate in a **circular economy**.

These benefits cannot be obtained without the setting up of **sustainable and judicious supply conditions across a territory** (renewal, appropriate quantities extracted) to guarantee minimum impact on the environment, and beneficial impact in certain cases. It is through the diversity of materials and techniques capable of meeting needs and through a territorial approach that it is possible to reduce pressure on ecosystems.

Numerous practices and initiatives linked to the use of sustainably procured materials exist in Africa, as well as circular economies based on reuse and recycling, either linked to traditional and informal practices or as part of private and public strategies. This is also true in urban or peri-urban environments where the use of earth is common. It is essential to encourage and promote these practices in the long term. Furthermore, this can contribute to better conservation of existing traditional buildings, which constitutes another essential lever to reduce the burden on the environment while being a source of substantial savings.

Hotel Le Djoloff, Dakar, Senegal
Architect: David Guyot. Company: #ELEMENTERRE



CONTRIBUTING TO A SUSTAINABLE AND RESILIENT FRAMEWORK AND ENVIRONMENT

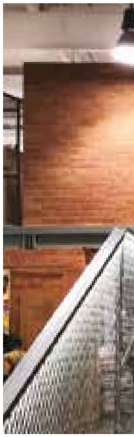
It is not uncommon to see local materials being criticised for being fragile, for having a short life span or for not being covered by specific standards. These criticisms question their capacity to meet the essential objectives of any construction (structural stability, durability, etc.) and especially to be used in contexts subject to natural hazards (earthquakes, cyclones, floods, etc.).

However, cultural heritage and local building cultures give us good indications of what it is possible to build, with life spans often exceeding a hundred years, using materials whose mechanical properties, if measured in a laboratory, would be considered to be poor. What explains this?

From the point of view of a standard, each material taken individually is required to reach “minimum” performance levels augmented by safety coefficients to take into account various unknown factors (human, technical, contextual, etc.). The approach is “product” oriented and each product must be “impeccable” and *de facto* “oversized”.

From the point of view of building cultures, the building functions as a system in which each element plays a part. The performance is that of the system as a whole and not that of a given material, even if this does count. In many centuries-old earth constructions, wall samples have shown compression strengths of between 1 and 2 MPa whereas the standard for loadbearing masonry more often requires strengths above 2.5 MPa. In spite of this, these buildings have stood the test of time and are still in use. This is made possible by their architecture, the result of the builders’ expertise. The capacities of the materials are known and they are used in line with good practices with, in certain cases, a link with a maintenance practice which must be carried out at more or less regular intervals. This performance-based approach allows excellent durability and strength to be obtained with savings in material.

Regarding more particularly the “disaster-resistant” properties of certain materials, once again we need to avoid looking at them too much in isolation. In most construction systems adapted to natural hazards (earthquakes, cyclones, floods, etc.), it is not the materials themselves which provide such properties but the sizing and the specific construction measures adopted. Taking natural risks into account requires first of all carefully choosing the siting of buildings (and of human settlements as a whole) to avoid disastrous consequences due to site effects or topographical effects in the case of earthquakes, floods or extreme winds. In terms of the building itself, knowledge of risks will impose the use of certain construction systems such as, for example, substructures in stronger materials (for floods) or roof frame anchoring systems (for winds).



In most at-risk areas around the world, construction traditions are full of examples of good practices and of taking into account of the natural hazards to which populations are exposed. These solutions are increasingly being documented. They can be subjected to reverse engineering practices which, by re-examining them, allow solutions able to improve their resilience capacities to be proposed. This new practice in the field of local materials is one of the major contributions of the past few years and has a high potential to contribute to the necessary adaptation to climate change.

CREATING A BUILT ENVIRONMENT CONTRIBUTING TO THE WELL-BEING OF OCCUPANTS

There is a very wide variety of traditional architectures in local materials which meet local physical requirements to allow people to live as well as possible and develop their activities. Architecture is inseparable from the concept of well-being, both physical and psychological. These architectures thus often offer a range of solutions to guarantee the best possible hygrothermal conditions and comfort and strike a balance between space, culture and a feeling of security.

The varied characteristics of these materials (massive, light, porosity, humidity and temperature control, etc.), combined or not, can meet requirements to adapt buildings to the various climatic conditions encountered on the continent, in accordance with “passive” design strategies (bioclimatic architecture) allowing an optimum level of comfort to be guaranteed for the occupants. This constitutes genuine added value in the face of climate change which calls for adaptation of housing.

The quality of the spaces created and their alignment with needs and uses (privacy, circulation between various spaces, size and volume, colour and texture, etc.) allow better living both for individuals and families and for communities.

Lastly, a material such as earth has demonstrated its capacity to provide good protection during conflicts, being able, unlike cement breeze blocks, to prevent bullets and small projectiles from passing through walls.

Throughout their life cycle, local materials have qualities enabling effects on the health of their users and producers to be reduced.

CULTURAL IDENTITY AND MODERNITY: BRINGING SUSTAINABLE CONSTRUCTION INTO LINE WITH VERNACULAR ARCHITECTURES

As in other regions of the world, all over Africa populations have created their habitat by adapting to the specific characteristics of their territory and by making judicious use of the resources available locally. The forms in which local materials manifest themselves change according to the know-how, uses, purposes and constraints concerned. A single material can indeed offer a variety of uses giving rise to forms of habitat adapted to their environments.

In many countries, these architectural heritages in earth, stone, wood, plant fibres, etc. are sources of pride and strong cultural symbols, many of which have already been listed as World Heritage by UNESCO.

Old town of Djenné, Mali

However, traditional techniques and geo-sourced and bio-based materials have generally been forgotten in modern building construction and ignored by research and training, amplifying their negative image. Technical and architectural standards tend to be imposed, contributing to the abandonment of a large amount of building expertise and greatly jeopardising cultural diversity, a fundamental component of sustainable development.

Promoting cultural diversity

In an environment which globalisation is making uniform, architectural heritages are a strong element of cultural identification. Rediscovering and promoting these highly diversified “building cultures” is a way to preserve the identity of the peoples who developed them and recognise their social values. Recognising these values means respecting and recognising cultural diversity as an essential component of sustainable development. It means contributing to its preservation in order to pass it on to future generations while at the same time facilitating their necessary adaptability.

Encouraging vernacular modes of construction must not be seen as a backward-looking approach. On the contrary, heritage is part of a living and evolving process with practices which have changed over time according to social dynamics and technical developments. It is possible to assist in changes or to propose adaptations, both with regard to the specific aspects of housing which pose a problem, such as for example the difficulty in procuring high-quality wood, and also in order to meet current expectations and convey an image of modernity. Especially as this can be done at costs which can remain extremely reasonable.

1. Wadi El Gemal Visitors Centre, Egypt; Architect: Ramses Nosshi / Egyptian Earth Construction Association
2. Individual villa in La Somone, Senegal; Architect: Atelier F
3. Hotel Onomo, Bamako, Mali Architect: Arnaud Goujon

Identifying, promoting and updating: sustainable construction is not just a technical issue but also a matter of meeting a twofold challenge, that of **preserving the qualities and values of traditional architectures while at the same time conveying an image of modernity**. Such an approach is then able to generate renewed confidence and pride among populations, enabling endogenous development to be triggered.

Drawing on vernacular genius for a contextual and innovative architecture

Built under sometimes difficult conditions, and tested and perfected over the centuries, vernacular architectures are extremely sophisticated beneath their apparent simplicity and are precious sources of information and inspiration to understand how territories and the resources they contain have been developed. It is through an in-depth analysis of the knowledge and practices of a region that it is possible to innovate and facilitate the emergence of architectures which can simultaneously be vernacular, in the sense of being the product of a place, and contemporary.

Research into this knowledge can be applied at all levels: on the level of building materials, techniques and processes, but also on the level of architectural compositions, of the siting and development of inhabited areas (urban or rural) and lastly of land management systems. Reverse engineering methods which can be applied in a multidisciplinary way (architects, engineers, sociologists, etc.) turn out to be well suited for this purpose, and can also deal with questions concerning standards and regulations. It is then essential that these lessons be taken into account in education on building and, beyond that, land use planning.

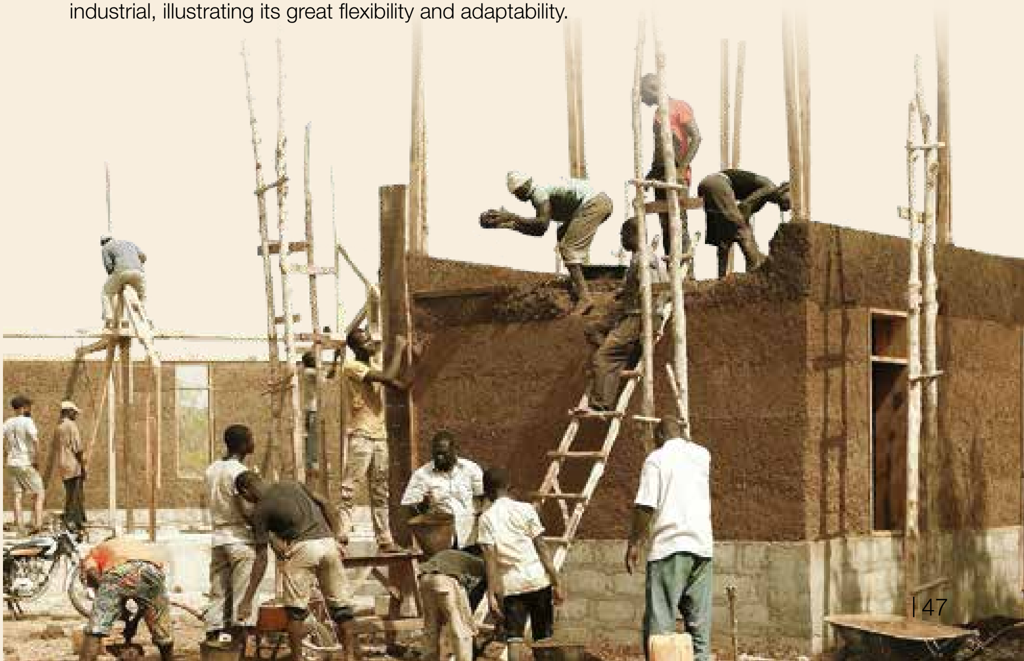
4

OUTSTANDING PROJECTS AND PRACTICES IN AFRICA

Opposite, left:
Diapalante Centre, Saint Louis, Senegal Architects: Suzanne Hirchi and Laurent Biot. Company: #ELEMENTERRE
Opposite, right:
Xewa Sowé Children's Centre, Benin; Architect: Collectif l'Harmattan Architecture

The aim of this "case studies" section is to present to the reader a number of recent projects illustrating the diversity of local materials in construction and their application and use in highly varied contexts, environments and situations in Africa. The intention is not to be exhaustive or in some way "representative" but to show what is possible in a concise form. The choice of this or that project does not reflect any particular "recognition" on the part of the authors but a desire to highlight and promote those projects whose approach is innovative and contributes to sustainable development goals. Many others could have been chosen, but it was necessary to make a selection and avoid highlighting projects already abundantly covered in the media or on the Internet. It was not a question of being exclusive either, but of using often little known or unknown examples to illustrate the reality, relevance and vitality of these local materials.

The apparent predominance of earth among the local materials cited in these examples is not surprising given its very ancient and widespread use in various forms throughout the continent. This material, as in the past, is almost systematically combined with other materials, both local and thermo-industrial, illustrating its great flexibility and adaptability.



FOCUS

CONTEXTUAL CONTEMPORARY ARCHITECTURES

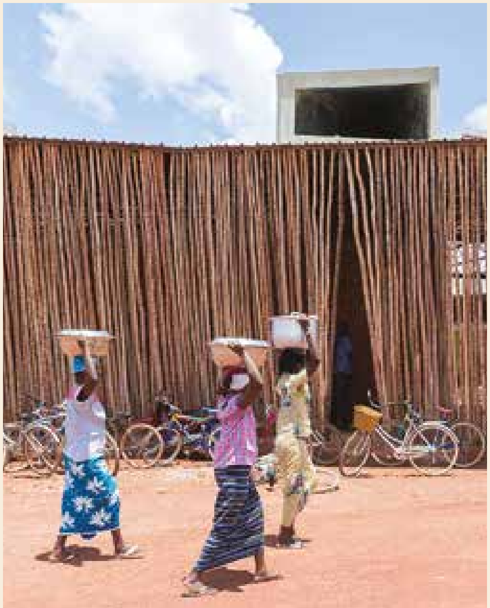
Since the early 2000s — on the African continent — numerous architects and designers have been facilitating the emergence of a profoundly contextual architecture, backed by a an environmental and civic commitment, seeking to break with an architecture which was trying to be globalised to the point of losing the cultural singularity of African cities. These architects express their creativity by highlighting the chain of ecological, social and cultural values of an architecture which draws on local resources: raw materials available under their feet or within easy reach.

These architectures prioritise modernised use of natural materials, bringing out their aesthetic potential and their

LYCÉE SCHORGE KOUDOUGOU, BURKINA FASO (2016)

ARCHITECTS: DIÉBÉDO FRANCIS KÉRÉ
MATERIALS: STONE (CUT LATERITE BRICKS - CLB), UNSQUARED LOCAL WOOD, CONCRETE, STEEL

The lycée is built by local artisans trained in the CLB construction technique, a technique used locally. CLB and unsquared local wood are locally available. The design references the circular plots of African villages for protection against winds and dust allowing the school to function with a private inner courtyard. The bioclimatic strategy of Francis Kéré's projects is based on a ventilated roof deck, a false ceiling of ventilated jack arches, the inertia of solid walls and natural ventilation with wide openings, slits in the jack arches and wind towers.



plastic qualities which enable this unique freedom of form found in traditional architectures.

Today, proponents of contemporary contextualised architecture appropriate the intelligence of vernacular construction. They propose to change the way people see local know-how and materials, to learn to appreciate again the beauty of their multiple expressivities.

In the wake of pioneers such as Hassan Fathy, André Ravereau or Fabrizio Carola, new recognition is being given to earth, stone, wood and natural fibres for architectural productions embodying beauty and modernity while being culturally integrated in their context.

Photo: AFLK/Sofia Verzbolovskis

ELEMENTARY SCHOOL AND TEACHERS' RESIDENCE, FASS, SENEGAL (2019)

ARCHITECTS: TOSHIKO MORI ARCHITECT
MATERIALS: CEB, BAMBOO, THATCH, CONCRETE, CEMENT

The oval-shaped architecture of the school with a steeply-sloping roof is borrowed from the "impluvium" type vernacular homes in the region which allow rainwater to be collected. The roof frame is in bamboo, the roof is thatched and the walls are made of earth bricks. The building, built by local artisans, mainly uses local materials: thatch and bamboo for the roof, earth bricks for the walls. The architecture, the materials and details such as the openings in the walls keep the interior cool.

Photo: AFLK/Sofia Verzbolovskis

HIKMA – DANDAJI CULTURAL COMPLEX, NIGER (2018)

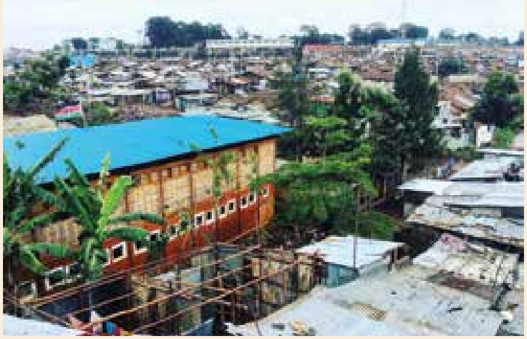
ARCHITECTS: ATELIER MASŌMĪ AND STUDIO CHAHAR
MATERIALS: RAW EARTH, ADOBE, CEB, REINFORCED CONCRETE

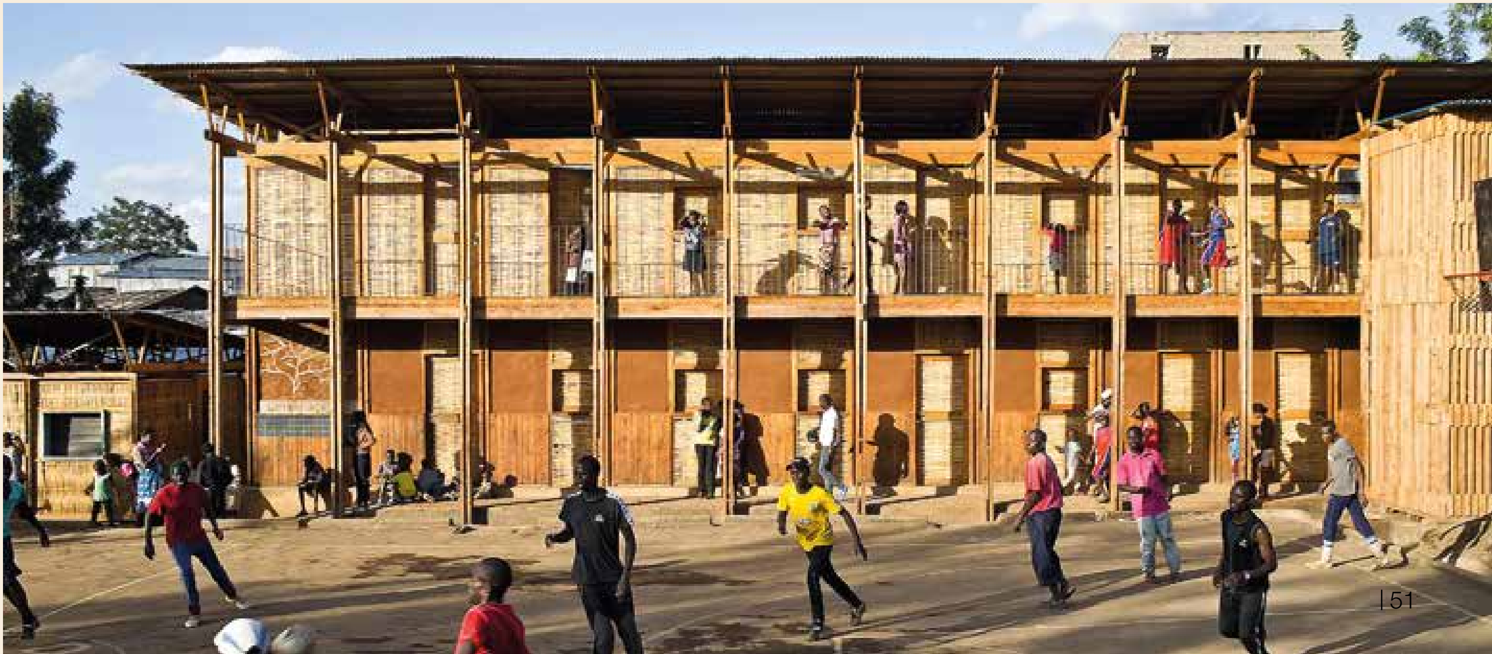
The HIKMA Complex in Dandaji includes the old mosque converted into a library and community centre for young people and women and a newly built mosque with a capacity of 1000 people inspired by traditional Hausa mosques. The project uses adobe, an existing material and technique, and introduces CEB. Most of the materials are sourced less than 5 km away, while the use of concrete is limited to structural elements such as the columns and beams. The construction drew on the know-how of traditional master masons in the area and masons mastering conventional techniques.

"WHY NOT ACADEMY" PRIMARY SCHOOL
NAIROBI, KENYA (2015)

ARCHITECT: GAETANO BERNI
TECHNICAL CONSULTANT: DAVIDE PEDEMONTE
MATERIALS: WOOD, BAMBOO, EARTH, LIME, FIBRES

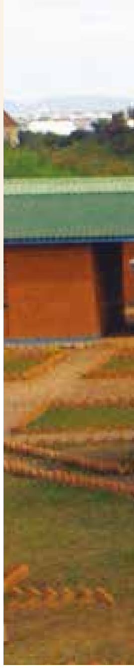
The school is located in Nairobi, in the suburban district of Mathare. It was built together with the inhabitants of the neighbourhood. The building is constructed with a wooden frame and wattle-and-daub, a traditional technique known to the inhabitants which was improved to increase the building's comfort and durability. The panels use bamboo wattle and, for the upper floor, a mortar of earth and plant fibres (sisal) is applied and covered with a coating stabilised with lime. The structure and its filling thus make the project easily adaptable; this flexibility has allowed it have extensions made to it due to the success of this school in the heart of the neighbourhood.





Accrediting local materials and know-how and restoring inhabitants' pride

CASE STUDY



Lubumbashi Reception and Training Centre consisting of several buildings in CEB and MEB. The central building was constructed in MEB.

PROMOTION OF ADOBE BUILDING CULTURES IN KATANGA, DEMOCRATIC REPUBLIC OF CONGO

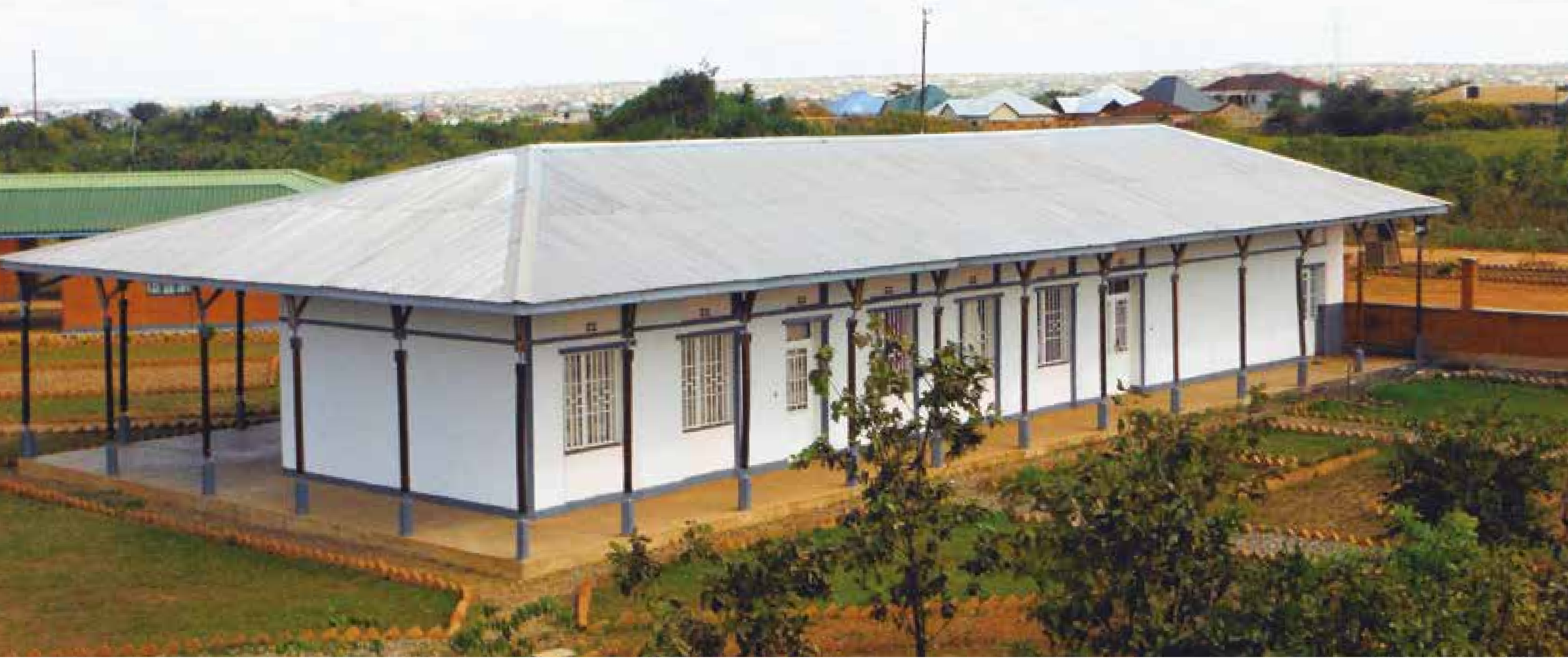
In Katanga, adobe construction is very common in rural and peri-urban areas and secondary towns. An assessment of local building cultures led to the observation that, despite the existence of very rich know-how, certain bad practices have emerged which contributed to downgrading the image of these raw earth habitats. For example, due to the influence of fired bricks, the dimensions of adobe bricks have been reduced, leading to the building of over-thin walls. In addition, wide, four-sloped roofs in plant materials are sometimes replaced by single-sloped sheet metal roofs which no longer protect the walls in the event of heavy rain.

Today, adobe, called *Tchimba brick*, has become the default material, synonymous with poverty and fragility, accentuating the lack of attention paid to its maintenance. This leads to a denial and loss of know-how despite the fact that this know-how provided appropriate and economical solutions for quality housing. Families now aspire to build their houses in fired bricks. However, these bricks are very expensive, they are ultimately not very sustainable given today's practices and their production contributes significantly to deforestation.

Since 2012, as part of its strategy to combat deforestation, the Diocesan Development Office (DDO) in Lubumbashi has launched various pilot projects to promote raw earth architecture through the construction of social facilities. With international financing, the DDO has prioritised the use of stabilised Compressed Earth Blocks (CEB) rather than adobe, which is too badly connoted. It is aware that, although the use of CEB is interesting as an innovative, aesthetic and sustainable alternative to fired brick, it nevertheless remains unaffordable for the majority of people and has less potential to revalorise the local heritage and its building intelligence. The DDO has thus helped several rural communities to build their primary school in adobe.

From 2014 onwards, the DDO sought to overcome prejudices by reinforcing the promotion of adobe under the name "Moulded Earth Blocks" (MEB). It launched the construction of the Reception and Training Centre, the imposing central building of which was built in MEB. It then contributed its "MEB" expertise to several social

Adobe is here henceforth referred to as MEB to convey a more contemporary image of the material, which is produced according to precise technical specifications. This is a guarantee of reappropriation of the technique.



facility and housing projects, such as the GRET project in which one third of the 150 houses were built with MEB instead of fired brick, in line with the beneficiaries' choice. These houses age better and have brought innovation to the local techniques of which the community is now very proud.

Building on these experiences and their lessons concerning support methods and technical aspects, the DDO has since 2018 integrated improvement of housing in its support programme for agro-ecological development of peasant families. The principle is to draw on local intelligence and processes of habitat production (mutual aid systems and self-building) to restore pride. Qualitative improvement is obtained by providing technical and social support to families who can finance their housing: support for traditional mutual aid systems and assistance in design, brick production and construction. Each project and each building site provides an opportunity to train several masons in the locality, which allows a wider impact beyond the direct beneficiaries.

Training of masons on the building site: reinforcement of the base of the wall by a wear mass and surface treatments of the external walls based on women's know-how.

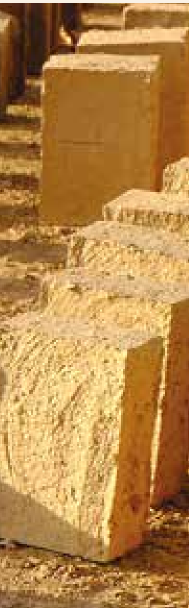
Combating precarious housing in urban environments:
supporting inhabitants to make informed choices for their housing

CASE STUDY

SOCIAL PRODUCTION OF HOUSING IN THE UNPLANNED AREA OF BOASSA IN OUAGADOUGOU, BURKINA FASO

Ouagadougou's uncontrolled growth has led to a housing crisis and the development of numerous informal and self-built neighbourhoods known as "unplanned areas" on its outskirts. The aim of the authorities is to work towards the improvement and better integration of these neighbourhoods. Indeed, the evictions followed by the development of this type of neighbourhood have become increasingly complex and a source of social tensions. The strategy now adopted is therefore to maintain the populations on site and support existing developments. This nevertheless requires these developments to be better documented and better enhanced.

In the unplanned area of Boassa, 73% of the population build their homes with raw earth (adobe) masonry and light sheet metal roofing. This is an economical and affordable solution because it allows self-building. However, due to ignorance or choice, and because of the risk of eviction, this housing remains of unsatisfactory quality and, above all, has difficulty in withstanding recurrent floods and violent winds.

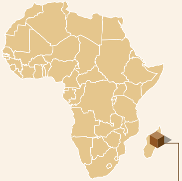


Since 2016, in response to this situation, the Burkinabé association YAAM Solidarité has been helping inhabitants and players in this neighbourhood to improve their housing and their living environment in general. This support is provided by involving the inhabitants throughout the process, making it possible to draw up shared assessments and define action priorities for housing but also for each street, each block and the neighbourhood as a whole. For this purpose, consultation sessions are organised to assist in collective awareness of the potentials and constraints of the region in terms of housing production and urban development.

Concerning the housing aspect, a revolving financing fund and a technical assistance system have been set up. Each inhabitant has access to information and can receive help in understanding the qualities and defects of his home, enabling him eventually to make judicious choices for his building or improvement project. Within this framework, in addition to awareness workshops, prototypes and demonstration buildings have been built, providing an opportunity to train artisans in the neighbourhood. Lastly, technical data sheets listing existing or new good building practices are made available to the inhabitants of the neighbourhood.

Incremental housing prototypes built in 2018 following a participatory process of co-design with the inhabitants of the neighbourhood.
The housing models proposed, due to their design but also their method of production, have a cost ranging from €80 to €200 per square metre which can be affordable for 40 to 60 % of households, these households being unable to afford the existing "formal" market (from €250 per m²).

The project conducted in Boassa is considered to be a success. This is essentially due to the initial effort to understand the mechanisms at work and the local housing production chains. More specifically, understanding methods of valorisation of local materials proved to be essential not only for the economic aspect but also to adapt the solutions to urban pressure, which reduces the areas available for extraction and processing. Here, valorisation of raw earth brick therefore requires the promotion of innovative building solutions which involve combined use of industrial materials, mainly sheet metal and cement. Moreover, these solutions are able to interest the target populations because they remain very affordable.



Using local resources to enable populations to (re)house themselves

CASE STUDY

SUPPORT FOR THE SETTLEMENT OF PEASANT MIGRANTS, MADAGASCAR

Recent statistics have shown that 91% of the Malagasy population live on less than €2 per day. This poverty is even greater in high-density agricultural regions, driving many young people to migrate to other areas, particularly urban areas, despite the lack of opportunities there. Conscious of these difficulties, successive governments have developed policies to support the settlement of migrants on lands presenting genuine potential, with the creation of new villages.

The Zoma association has been implementing one of these programmes since 1990. Concerning the housing aspect, each migrant family receives assistance in building their own house, drawing on local resources and possible support from other members of the village community.

The families choose between different variants for their house. The models are suited to the climate and the local environment (frequent cyclones). The building materials available on the spot essentially consist of raw earth for the walls (adobe and cob), wild wood and thatch for the roof. The latter material is not really promoted by Zoma, however, being seen as not very acceptable to the beneficiaries and subject to fire risks.

The materials and techniques promoted have proved to be suitable and replicable. All of the families who built extensions to the basic module chose to reuse them. The only variation is systematically in the roofing material, as inhabitants, being unable to afford quality sheet metal, resort to lower-quality sheet metals or to the production of thatched roofs, which are in fact generally of good quality.

It therefore seems essential to question the reluctance of organisations to facilitate the use of certain materials (in this case, thatch) even though helping to promote them would make it easier to achieve the set objectives, namely genuine autonomy of the target populations (through appropriate cost and technicality). Other benefits of thatch are high habitation quality (thermal and sound insulation and resistance to violent winds), reduced environmental impact and generation of local economic activity.

Houses are almost entirely built from the various parts of a fast-growing native plant, the ravenala or traveller's tree, the emblem of Madagascar.

CASE STUDY

POST-CYCLONE RECONSTRUCTION IN A DIFFICULT-TO-ACCESS REGION, MADAGASCAR

In February 2012, Madagascar was hit by Cyclone Giovanna and then by Tropical Storm Irina, affecting 332,000 people and causing considerable damage. After one month, less than 15% of the households hit by the disaster had been able to rehabilitate their home to an acceptable level.

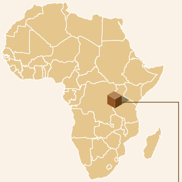
This fact led Catholic Relief Services (CRS) to start a reconstruction project in a difficult-to-access region, using a community-led process allowing remote management. The theory was that, by relying on local resources and capabilities, and particularly on the population (participants in the project and local authorities), and by providing appropriate technical assistance, it would be possible to obtain high-quality results at minimum cost and reinforce the appropriation and the durability of the results.
The local beneficiaries and artisans were involved in the design process in order to make sure that the houses were culturally acceptable and suited to the environment.

Ravenala is used for the floor (trunk), the walls (stems) and the roof covering (leaves). These materials enable rapid, low-cost construction of houses and temporary shelters in the event of cyclones, and constitute a source of income for village communities.

The design incorporated local building practices while proposing improvements for better resistance to natural hazards. The local artisans were trained and local committees were set up to supervise the construction work. The result was: a housing unit could be built in only five days.

This process was a genuine success. It allowed 598 families to obtain safe housing within three months. All the constructions used local materials, mainly derived from a palm-shaped plant (see opposite) and other local wood species. The participants and the authorities appreciated the quality of the constructions. The very affordable cost of the 12 m² housing units, amounting to €120 (materials and labour), made the solutions replicable: one month after the project, eight other families had already rebuilt their house in accordance with the technical recommendations of the project. The same approach was subsequently adapted for the reconstruction programmes in 2017 and then in 2019.

Use of ravenala reduces pressure on the forest (slow-growing trees). However, the trees and plants most suitable for building are becoming increasingly rare and strategies for better forest management should also be developed.



Promoting eco-responsible architecture in line with local needs

CASE STUDY

PROMOTION OF AFFORDABLE HIGH-QUALITY EARTHEN ARCHITECTURE IN BUSHENYI, UGANDA

In Uganda, forest cover is rapidly diminishing. This is to a large extent due to the building sector which uses wood for structural purposes (posts and roof frame) and for firing bricks. The price of building timber has become unaffordable, which means that the quality of housing is deteriorating while the use of fired brick is increasing, and with it the deforestation process.

To combat this process, the local government of the Bushenyi district proposed to use the building of school facilities to demonstrate the possibilities for improvement of the local populations' habitat while at the same time being more environmentally responsible. This was carried within the framework of a partnership bringing together complementary expertise: Makerere University, two technical schools and a Ugandan NGO.

Two avenues for work were identified:

- Improvement of existing building systems (wattle-and-daub) to reduce the use of wood and increase sustainability;
- Promotion and improvement of more recent (adobe) or entirely new (CEB) building techniques as a partial or total substitute for fired brick.

Between 1999 and 2004, a network of expertise was constituted, based on:

- Construction of demonstration buildings;
- Development of educational kits usable by vocational high schools;
- Development of promotional materials;
- Awareness campaigns for local, national and international decision-makers.

Building site combining different local materials (fired bricks and MEB)

The project emphasised on-site training which simultaneously benefited the local artisans and technicians and the students, teachers and instructors of the technical schools and Makerere University. This also led to the introduction of a training module in earthen architectures and economical housing in the teaching programme of the Makerere University architecture department.

For public buildings, high-quality, affordable and sustainable solutions were developed, reducing building costs to a range of €45 to €55 per square metre (compared to €60 to €70 per square metre for conventional technologies). A considerable proportion of the cost is accounted for by labour (local artisans and workers): between 25% and 35% of the total investment compared to 10% to 20% for conventional solutions. Lastly, reduction of the use of fired bricks enables a saving of up to 14 m^3 of wood per classroom.

As regards housing, adobe houses use a smaller amount of wood. Houses in “improved wattle-and-daub” offer a better image and consume half as much wood as the usual practices. The proposed improvements require an additional but reasonable investment, and this additional cost is quickly recouped with the extension of the building’s life span, which is at least doubled.

This effort to reverse engineer local building cultures has been well received by the communities concerned. It has allowed the building of school facilities in the district to be speeded up, and appropriation of housing improvement solutions has been observed among the populations. To have a more significant and lasting impact, it would be useful to complement these initial results with monitoring mechanisms and, if possible, mechanisms of financial support for the most vulnerable households.

Demonstration buildings in CEB and MEB and fired bricks in Kigari (Bushenyi district)

	Fired brick	Adobe	CEB
Construction cost	3,290 €	2,600 €	2,780 €
Investment in labour	263 € (8%)	660 € (25%)	570 € (20%)
Proportion invested in the locality (Labour and local materials)	364 € (11%)	920 € (35%)	730 € (26%)
Volume of wood used	16 m^3	6 m^3	2 m^3

Comparison of costs and volumes of wood used for one classroom (useful floor area 48 m^2). Solutions of equivalent quality (Ugandan standard: 60 years). 2004 data

CASE STUDY

AN INTEGRATED APPROACH TO PROMOTION AND FORMALISATION OF THE ARTISANAL TIMBER SECTOR IN CENTRAL AFRICA

In Central Africa, the domestic and regional timber markets are growing rapidly. Rapid demographic growth, urbanisation and the economic development of the region are the reasons for the increase in domestic demand for sawmilling, which in many countries is already greater in volume than industrial exploitation for export markets.

However, this market is mostly supplied by an informal sector. Domestic demand is therefore supplied by small-scale operators who, although organised, operate mainly outside the legal frameworks. The sector generates jobs and significant income in rural and urban environments. In Cameroon, for example, small-scale sawmilling creates 45,000 direct jobs and generates more than 20 billion CFA francs (Cerutti, Lescuyer 2011). However, these jobs are insecure and artisanal operators have irregular income while being vulnerable to corruption and abuse from the authorities.

This informality makes solid growth of their activity difficult for entrepreneurs and contributes very little to public revenue. This situation also aggravates forest degradation. In spite of this, sustainable use of forest resources can be a driver of sustainable development in Central Africa.

Transformation of the domestic market

To remedy this situation, the Center for International Forestry

In some countries in Central Africa, the volume of wood sold on domestic markets exceeds exports.
Wood market in Yaoundé, Cameroon

Research (CIFOR) has launched the "PROFEAAC" project ("Promoting and Formalising Small-Scale Logging in Central Africa") which will be implemented by the end of 2023. The aim is to reduce forest degradation in rural areas in Central Africa. Financed mainly by the French Facility for Global Environment (FFEM), the project proposes an integrated approach of formalisation and development of small-scale logging, ranging from wood resource management to demand for sawmilling in domestic markets.

Firstly, the project aims to strengthen the capacity of small-scale loggers to operate legally by obtaining a permit or certificate, and to develop their commercial and financial skills to improve their living conditions. It also aims to promote small-scale logging in strategies to develop decentralised territorial entities in order to improve long-term governance.

To support formalisation from the consumer's point of view, the project will set up communication and advocacy strategies aimed at individual consumers and the public and private sectors, particularly in urban markets.

Lastly, in order to minimise the contribution of small-scale logging to forest degradation, the project aims to develop low-cost methods of estimating and monitoring environmental impacts, and to promote local wood species regeneration and reforestation measures and agroforestry measures.

Target countries
The project will be deployed in Cameroon and in the Democratic Republic of the Congo (DRC), where the volume of small-scale sawmilling is estimated respectively at nearly 2.1 million and 3.4 million cubic metres (round wood equivalent) per year. It will be conducted within the framework of strong partnerships with the government institutions concerned and with various international and national technical partners (CIRAD, IRD, Tropenbos DRC and Ilexa-Bois).

Although Cameroon and the DRC have very large domestic timber markets, their governance systems and the characteristics of the demand call for different solutions.

In Cameroon, the project chose two pilot sites in the East and Centre which supply the markets in Yaoundé. The aim will be to promote Logging Permits, a provision set out in the Forestry Act of 1994 and currently under revision which would enable small-scale operators to log and market a volume of wood corresponding to their technical and financial means.

In the DRC, the project will focus on the province of Tshopo and the markets it supplies, especially Kisangani. In this country, two certification options will be tested, the Artisanal Logging Permit (ALP) for individual logging and the Local Community Forest Concession (LCFC) for community forestry.

The iterative approach: an essential corollary to the territorial analysis

CASE STUDY

RURAL DEVELOPMENT OF MAYAHI IN NIGER

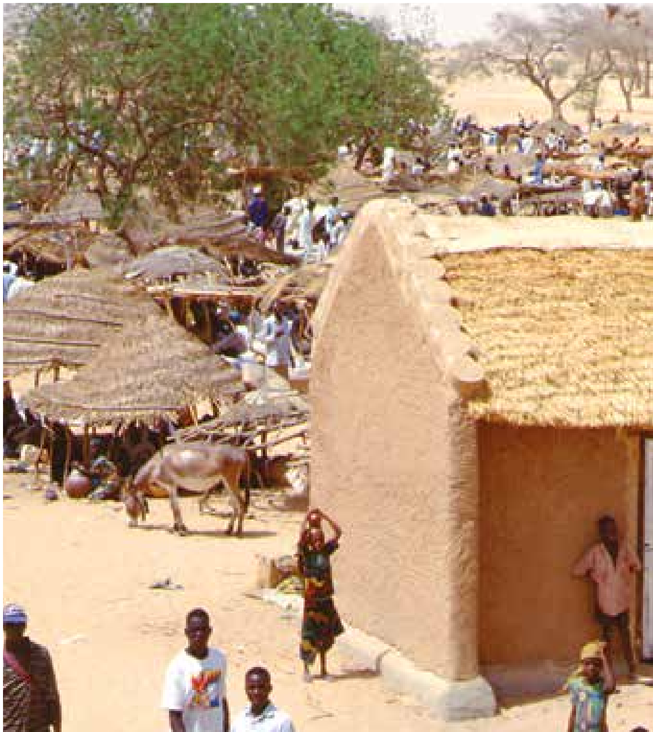
Niger has many regions affected by desertification phenomena. To combat the resulting rural exodus, the Mayahi rural development project, supported by the FAO (the United Nations Food and Agriculture Organisation) and conducted in the late 1990s, aimed to improve the living conditions of populations by:

- restoring a sustainable agroecological balance,
- increasing agricultural and livestock production, and
- diversifying economic activities generating lasting employment.

In the construction part of this project, the primary concern was the building of various agricultural, business, education and health facilities, but it was also proposed to contribute more generally to the improvement of housing.

For this purpose, an initial diagnosis of the territory was conducted in a participatory way, revealing a diversity of needs, practices and uses while enabling the potential of local resources (materials and skills) to be identified in connection with environmental challenges. This implied taking into account the specificities of each place, both in terms of types of facilities and in terms of appropriate technical solutions and reinforcement of skills.

In response, an iterative process was set up, based on the construction of a variety of demonstration buildings. The construction of these buildings was the subject of reflexive feedback conducted with the various stakeholders on the acceptability of the proposed solutions, their adaptation to local needs and capacities, and also on the possibility of setting up a regular maintenance process. Local solutions were favoured (adobe and straw roofs) while





The iterative approach of the FAO's project and its concern to provide specific responses to the various needs expressed by the population led to the proposal of a great variety of technical and architectural solutions (opposite, on the left and above) and to the setting up of training programmes mainly directly on the building sites.

innovative wood-free construction solutions (arches, vaults and domes) were proposed.

These prototypes made it possible to check the appropriateness of the envisaged technical solutions and make choices with the stakeholders for each type of building (infrastructure or housing). They also allowed more precise identification of the related needs in terms of:

- cultivation and management of plant species used in traditional building;
- supply of appropriate equipment (carts, tools, etc.);
- training of artisans, instructors and public service technicians.

This going back and forth between action in the field and programming of this section of the project was repeated, leading among other things to a particularly innovative practice: building rural market shops for dissemination of and training in rural housing improvement techniques. In addition, noting that the facilities cost between 30 % and 45 % less than conventional solutions, a new method of calculating quotations that better values labour was proposed to local contractors, so that they would not lose out and would act as promoters of these solutions.

In the space of four years, affordable housing improvement proposals proliferated through the construction of more than 200 demonstration buildings and facilities built by local companies. Numerous skills were reinforced with, in certain villages, the observation of a genuine qualitative leap in private constructions, at very reduced costs.

The results of this project were reused in other school infrastructure projects conducted by UNICEF but also again by the FAO, particularly in a similar project in the N'Guigmi region bordering Lake Chad.

Improving the resilience of populations in the face of disasters and the effects of climate change

CASE STUDY

REDUCING VULNERABILITY TO FLOODS IN WEST AFRICA

West Africa is experiencing a steady increase in floods. These are causing increasing damage to housing and further impoverishing already very deprived populations.

In response to the growing risks linked to climate change and following the major floods in 2007 and 2009, the International Federation of the Red Cross wished to support strategies to reduce vulnerability and adapt housing in these regions.

In 2009, a pilot project was launched by the Red Cross Society of Côte d'Ivoire to acquire tools and methods aimed at documenting, disseminating and if necessary improving existing good building practices capable of increasing the resilience of populations. Other National Red Cross Societies (in Senegal, Benin, Nigeria, Togo and Mali) were subsequently involved in the process. This made it possible to identify solutions suited to other contexts and facilitate exchanges between populations already accustomed to these risks and those in regions newly confronted with them.

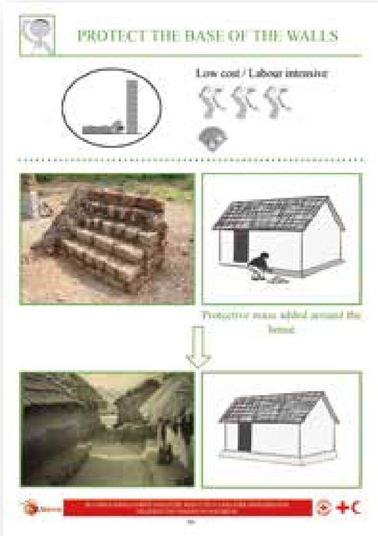
Awareness, demonstration and professional training activities were set up to provide the population with technical solutions for improvement of new and existing buildings which were appropriate to the local contexts and capacities. These adaptation measures draw on local building cultures, thus ensuring their accessibility and their replicability, and almost systematically prioritise the use of local materials such as raw earth, stone, wood or fibres.

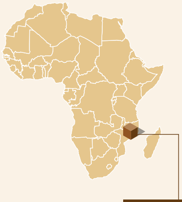
The fact nevertheless remains that the flooding risk is often linked to poor siting of homes or to development work which does not sufficiently anticipate this type of impact on a region.

GOOD BUILDING PRACTICES

Various building practices are promoted according to variants adapted to different budgets or levels of risk exposure. Thus, to protect the base of walls, it was proposed, among other things, to:

- add a protective mass of earth;
- build on a raised platform;
- build a cement block/stone substructure and add a capillary barrier if necessary.





CASE STUDY

House self-built in 2018 in Chinamacondo which withstood Cyclone Idai.
A great deal of building intelligence can be seen here, particularly in the aerodynamic roof and the wide veranda supported by high-quality pillars.

ENDOGENOUS RECOVERY CAPACITIES IN MOZAMBIQUE

In March 2019, Mozambique was hit hard by Cyclone Idai, considered to be the most powerful cyclone which has occurred in Africa, damaging more than 240,000 houses. The International Federation of the Red Cross quickly committed itself to reconstruction work with a desire to reinforce the existing building capacities and practices of the populations concerned. For this purpose, an analysis of local building cultures was conducted in order to identify the strengths and weaknesses of building and recovery practices in various rural and peri-urban communities which had been affected.

This analysis highlighted the capacity of the populations to repair and rebuild by themselves thanks to the resilience of the local building solutions. In particular, mixed timber and wattle-and-daub (pau-a-pique) houses are easy to repair or rebuild at minimum cost, because they allow recovery of the materials. In certain cases, good mastery and execution of traditional techniques enabled remarkable resistance to the cyclone (*see photo*).

However, weaknesses concerning the quality of the roofs or the base of the posts were identified. They were generally correlated to other causes such as, for example, the increasing difficulty in obtaining high-quality bio-based materials (wood and thatch) and a loss of traditional know-how. Populations are tending to replace certain materials and/or techniques with imported solutions which are less well mastered and which sometime aggravate pre-existing vulnerabilities.

One year after the start of the project, post-disaster assistance has barely reached more than 15% of the affected population. Sustainable housing solutions and solutions based on traditional practices, promoted by certain players, are still identified as “temporary” on the national level. This is despite the fact that conventional solutions resistant to natural hazards are financially and technically inaccessible for the affected populations and are therefore difficult to replicate. The various means set up could however have a greater and more long-term impact on the resilience of the populations if they were directed towards the vulnerabilities which affect local building practices, particularly those concerning devaluation of traditional know-how and access to available, high-quality local materials.

Developing a Skills and Certification Standard
for earth construction in Africa

CASE STUDY

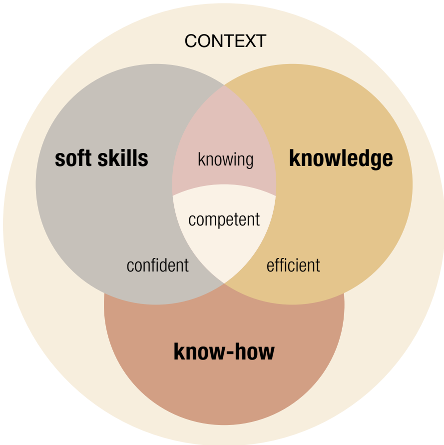
PROMOTION OF ECO-CONSTRUCTION ARTISANS, LUBUMBASHI, DEMOCRATIC REPUBLIC OF THE CONGO

In the city of Lubumbashi, the majority of the housing is built in artisanal fired brick, the manufacturing of which contributes heavily to air pollution and deforestation. Here, both brick production and the execution of work are very often of low quality. This is due to the fact that the work of the artisan, often lacking in professional training, receives little consideration. His payment is based on the costs of the materials (generally 30%) and not on his skills. This method of calculation encourages overconsumption of materials, a factor amplified by increased use of reinforced concrete and coatings to compensate for the mediocrity of the masonry.

In this context, since 2012, the Diocesan Development Office (DDO) in Lubumbashi has been leading a strategy of promotion of raw earth construction in which professional training is a major theme. The aim is to promote the intelligence of traditional load-bearing masonry (adobe and visible fired brick), proposing stabilised Compressed Earth Block (CEB) as an alternative to fired brick.

The DDO has already trained several teams of artisans on building sites and demonstrated the socioeconomic and environmental benefits of CEB and adobe. Paradoxically, however, this upsets small entrepreneurs, because these technologies, using smaller amounts of costly materials (cement, sand and steel), lead de facto to a reduction of the amount normally allocated to labour in the price of the building.

With this in mind, and to compensate for this problem, it is proposed that the method of payment be modified and based on the responsibility of each player on the building site. This new paradigm entails commitment, makes artisans more responsible for their work and encourages recognition of work well done



The AVCET system constructs learning according to the Skills-Based Approach (SBA) in order to make the professional autonomous and capable of adapting to all situations in his or her field of responsibility, and to promote mobility.

The ACVET system is available for four levels of responsibility:

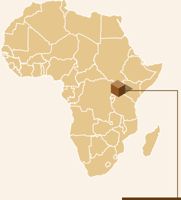
- **Crew labourer (brick-maker's assistant, bricklayer's assistant)**
- **Qualified worker (brick-maker, bricklayer)**
- **Team leader (brick-making and bricklaying)**
- **Site manager (coordinator of all trades on a building site)**

which deserves to be paid for. The aesthetics of CEB, which requires precision and rigour, is seen as an asset to facilitate a change in behaviour by artisans, who regain pride in their masonry, which is left visible.

Thus, since 2016, the DDO has linked up with the Salesian Education Office of the Congo (PBSCO) which supports several Vocational Training Centres. The aim is to introduce teaching of raw earth construction according to the Skills-Based Approach (SBA), promoted by the Ministry of Education since 2013, to ensure that vocational training better meets the real needs of the working world, particular micro and very small businesses.

In this approach, the DDO bases itself on the ECVET (European Credit for Vocational Education and Training) Earth Construction skills standard, adapting it to the context of the DRC. This system renamed ACVET (A for African) is broken down into knowledge, know-how and soft skills for four levels of responsibility. After complete adaptation, the ACVET tool could be disseminated by the Salesian network Don Bosco Tech Africa which coordinates 102 Vocational Training Centres in 35 African countries.

In answer to the fundamental question of remuneration, the ACVET tool includes a training module to reconsider the method of payment of construction players. Beyond that, the training programmes favour self-employability, because they incorporate the common denominators of the three techniques (adobe, fired brick and CEB) and adapt to customers' needs. By decompartmentalising trades, this facilitates, for example, the conversion of "fired brick" brick-makers into "raw brick" brick-makers.



Linking habitat
to quality of life

CASE STUDY

VOCATIONAL AND ACADEMIC TRAINING IN SUSTAINABLE ARCHITECTURE, ANGOLA

Angola experienced two long periods of war, firstly the war for independence (1961–1975) and then the civil war (1975–2002) which left a deep mark on the country. Under the national reconstruction and social development programme, various civil and religious organisations participated in the effort to rebuild social infrastructures by drawing on local materials, with the use of Compressed Earth Blocks (CEB) in particular. In all, more than 40,000 square metres of facilities were built in CEB, providing durable and high-quality results, including in terms of trained workers.

From 2010 onwards, certain players initiated more in-depth thinking on building processes and ways of living. Linking this with its education and sustainable agriculture programme, Caritas Angola launched the "Sustainable Architecture: improvement of rural housing" programme.

Analysis of the traditional adobe habitat and the building of a prototype gave a new turn to initiatives concerning earthen architecture in Angola. They led to the development of a new awareness, training and construction programme which better integrates the various players in the construction cycle, at three levels:

- the family and the community (artisans),
- the site manager (technical schools),
- the engineer and the architect.

An important component of the training programme, and one which has been progressively refined with experience, is the place it gives to the "modus vivendi", providing a new perspective, necessary in the Angolan context, which has highlighted the fact that quality of life is synonymous, among other things, with quality of housing.

The decision to make such an innovation was based on two observations:

1. The war changed every paradigm, including that linked to the act of building and inhabiting. It forged the idea of a temporary habitat and a break occurred in the transmission of know-how. The resulting deterioration in the quality and durability of traditional housing led to it being devalued among populations, even if people are well aware of the safety provided by earthen walls against gunfire.
2. Today, cement blocks are progressively replacing natural materials and, with the tendency to have only a few windows for security reasons, indoor humidity affects the comfort and health of occupants.

At a time when housing tends to be talked about in terms of functionality and material needs, it is not easy to engage in thinking about the "modus vivendi". The training

programme is thus based on a learning process which is intended to be:

- complete: in addition to the technical component on local materials (particularly adobe), the programme includes themes related to lifestyle, well-being and health.
- Inclusive and sustainable: it attempts to raise awareness by encouraging analysis and reflection so that the community can be autonomous in its future decisions.

Ultimately, the awareness and training programme on earthen architectures proposes to innovate on existing educational methods to enable students, through analysis and reflection, to understand the world better in order to rebuild society sustainably.





Local materials and technical and social eco-innovation in Senegal

CASE STUDY

TYPHA

In Senegal, typha is an invasive reed covering the River Senegal and Lake Guiers (Dakar's source of fresh water). It is a major ecological problem. Actions have been undertaken to eradicate it, but without success. More recently, research has been started to turn this nuisance into a useful resource. Under the PNEEB/Typha programme, work has been conducted to develop earth- and fibre-based insulating products enabling this envisaged resource to be used in products contributing to better energy efficiency of buildings and to a reduction of CO_2 emissions.

For this purpose, an inventory and a state-of-the-art report on the use of plant fibres in construction were drawn up, followed by an experimentation section associated with several seminars presenting the results, a demonstration section including training and an application section with a view to broad dissemination of the results. Some of the resulting products are currently used in construction projects such as the Diamniadio Ecopavilion (Dakar) or improved granaries in Matam.

Example of typha-based materials produced in the PNEEB/Typha project and used in the Diamniadio Ecopavilion project (Dakar): typha earth in insulating panels, typha thatch tile cladding, etc.

CASE STUDY

IMPROVED GRANARIES TO CONTRIBUTE TO FOOD SECURITY

In the Matam region, the problem of access to appropriate means of storage combined with droughts leads to a considerable loss of onion harvests, creating situations of economic and food insecurity. Marketing of harvests at the same time in the absence of storage leads to a drop in prices which jeopardises this important agricultural sector.

Thinking was launched between the stakeholders[1] with the support of their partners[2] to find viable solutions through, among other things, the development of improved granaries for more effective storage of harvests.

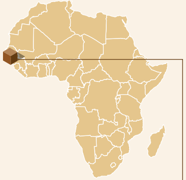
After a study phase, a first prototype granary with a capacity of fifty tonnes was built in 2019. Its design is based on a system of ventilated double walls in moulded earth blocks to insulate the storage space. A backup cold production system was added for additional cooling during the hottest periods. Typha elements were used on the ceiling under the roof to improve the building's thermal insulation. The first test campaign showed better results than standard practices, validating the technical and architectural principle: 80% of the thirty-five tonnes stored were still marketable after three months.

At the end of this phase, building began on a second granary with a capacity of one hundred tonnes with the inclusion of certain changes aimed at improving the energy efficiency of the building and facilitating its use: in particular, a wind tower and an underground channel should improve the storage conditions.

In the next three years, around thirty granaries will be built in local materials as part of a programme to develop social enterprise along the river. It will be done through the reinforcement of local players' capacities in production of materials and construction and maintenance of buildings, by means of training and the production of educational and technical documents.

Building site of the first prototype of an improved granary in Matam

1 Association Karwal Nguenar et Bossea (AKNB), local authorities, APOV (onion producers' association), Matam River Valley departmental federation of community management committees (Women's Promotion Group–GPF), FANSOTO association, Gaston Berger University of Saint Louis.
2 Entrepreneurs du Monde, CRAterre, Schneider Electric, Fondation EDF, Coopération Monégasque.



Evaluating to minimise the environmental impact of construction

CASE STUDY

COMPARATIVE ENVIRONMENTAL IMPACT OF A PUBLIC BUILDING, GUINEA-BISSAU

In Canchungo, the second biggest city in Guinea-Bissau, 90% of households live in poverty and living conditions are tending to deteriorate. It is in this context that the association GRDR *migration-citoyenneté-développement* has been participating since 2014 in the improvement of housing in several priority neighbourhoods through the promotion of sustainable housing. Numerous actions have been conducted among vulnerable families with the aim of henceforth promoting the use of local materials and sustainable architecture to the city's authorities and the formalisation of the building market.

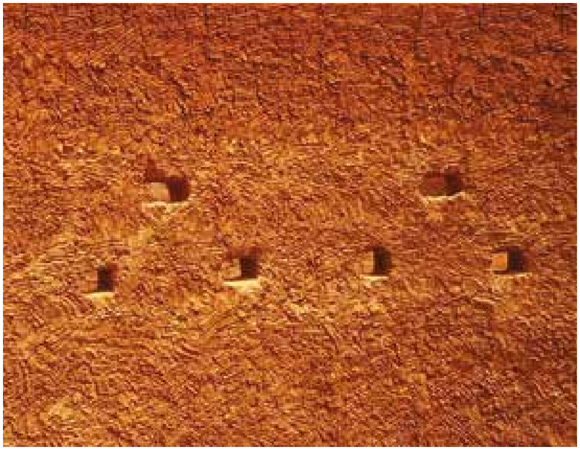
In 2019, GRDR launched with its partners (municipal authorities, decentralised departments of the State, etc.) the construction of a resource centre in local materials as an exemplary building in an attractive area of the city. Through this project, the aim is also to evaluate and attenuate the impact of building activities on climate change. An evaluation of the environmental impact (use of energy and greenhouse gas emissions or GHGE) was conducted concerning the building, comparing it with the impact of a conventional option in cement blocks.

The results show first of all that despite the use of cyclopean concrete foundations, which require less cement, in the project, **the foundations remain by far the biggest item in terms of impact**, especially in GHGE (70%), followed by the roof frame and covering. Very often the foundations calculation systematically takes into account the most unfavourable situation, whereas a ground study would enable oversizing and additional cost to be avoided. Stone foundations would also be of major benefit in this context, at least for housing solutions.

In addition, **the use of raw earth walls considerably reduces the impact compared to cement block walls**: 5 tonnes equivalent of CO_2 are saved for this building which has 230 m^2 of walls. The saving in GHGE would be even greater compared to fired brick walls.

For the roof frame and covering, however, the difference between the metal framework solution and the local timber frame solution is not significant. The inclusion of the impacts of the timber is at issue here, because, in this instance, as the local timber comes from an unmanaged forest (premature felling and trees not replaced), the data take into account the lost CO_2 storage leading to an unfavourable balance in terms of GHGE.

Texture of the cob walls of the Canchungo Resource Centre



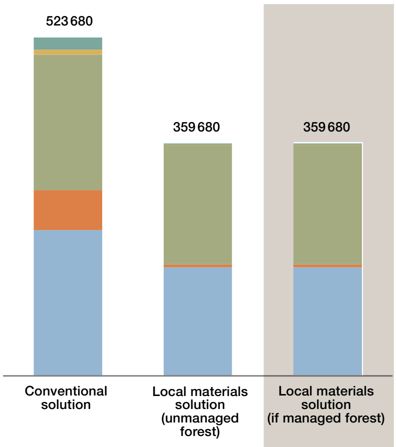
The Canchungo Resource Centre.

	Conventional solution	Solution in local materials
Foundations	Reinforced concrete	Cyclopean concrete (40% stone 60% concrete)
Walls	20 cm hollow cement block Cement coatings	Raw earth (adobe and cob) Earth coatings, sometimes cement
Roof Frame and Covering	Metal roof frame Aluminium-zinc sheet metal covering	Local wood roof frame Aluminium-zinc sheet metal covering
Joinery	Steel sections	Local wood
Paintwork	Vinyl and glycero paints	Lime whitewash on walls Glycero paint (roof frame)

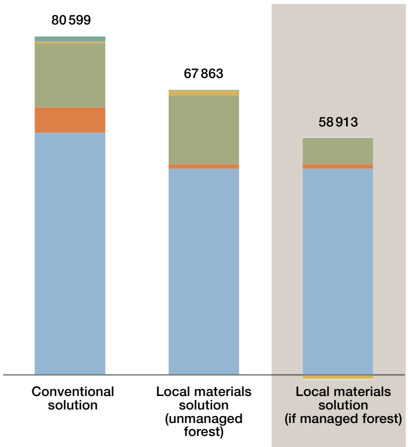
Construction choices of the options compared

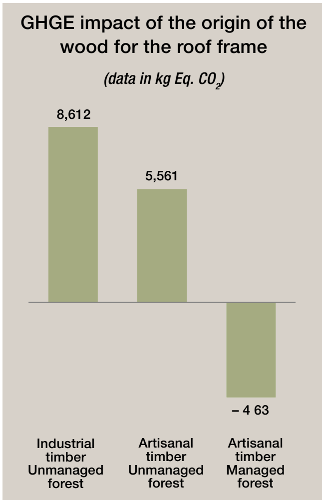
An alternative calculation was made for the case in which the forest stock would be sustainably managed, enabling the wood-based products to store CO_2, approximately 5 tonnes for the building studied. Another calculation hypothesis is proposed, considering industrial exploitation of unmanaged wood: the quantity of wood lost, the transport and the treatments would then considerably increase the impacts in terms of GHGE. **Correct management of the timber resource is therefore essential to reduce the impacts of the building sector.**

Non-renewable primary energy (MJ)

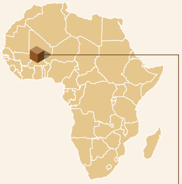


Greenhouse gas emissions (kg Eq. CO_2)



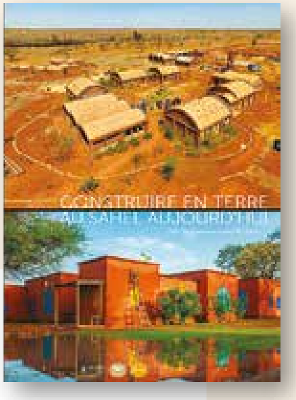


Paintwork | Joinery | Roof frame Covering | Walls | Foundations



Bringing players together for the development of local material sectors

CASE STUDY



A NETWORK OF PLAYERS FOR THE PROMOTION OF RAW EARTH IN THE SAHEL

The Sahel is the cradle of a unique architectural heritage and building expertise. The use of raw earth as a building material in combination with other materials has adapted itself perfectly to local ways of living and inhabiting, drawing on the potentials, dynamics and constraints of the environment. In a context in which judicious management of natural resources and the ecological transition are absolute imperatives, there is considerable renewed interest in this local resource and the knowledge which is associated with it due to its high potential to meet a growing demand, particularly in urban areas, for high-quality, healthy and ecological buildings. Specialised companies are proliferating and numerous projects are being developed. A genuine earth sector is emerging despite numerous obstacles (lack of recognition, training, regulations, etc.) slowing down its larger-scale development.

Noting this fact, players in the region have set up the FACT Sahel + network (Fédérer les Acteurs de la Construction en Terre au Sahel et dans les pays limitrophes) in order to facilitate the development of the sector. Taking the region's building cultures into account to serve contemporary earthen architecture constitutes the network's commitment to offer a wide range of innovative solutions to populations, whether rural or urban, poor or more affluent.

The main objectives are to organise interprofessional exchanges, to improve players' visibility, and to assert and disseminate a Sahel building identity respecting and promoting natural resources and local know-how while simultaneously boosting professional training of young people and women.

The ambition of such a network is to connect supply and demand (private and public) through a panel of wide-ranging and complementary expertise. The multidisciplinary nature of the members of the network, consisting of male and female artisans, decorators, artists, students, teachers, material producers, entrepreneurs, engineers and architects together with NGOs and builders' associations, is a major asset for the development and sustaining of earthen architecture at the local and regional level. This network engages in a variety of activities including communication, awareness-raising, promotion, training and transfers of knowledge between professionals by way of seminars, exhibitions, festivals, building sites, workshops, publications, experiments, etc., as exemplified by the travelling exhibition and the work Construire en terre au Sahel aujourd'hui (Contemporary Earthen Architecture in the Sahel). FACT Sahel + supports and co-organises the Bogo Ja festival with the Bougou Saba association, an event aimed at preservation of cultural and architectural identity and preservation of the environment, based around the decoration of earthen houses in Siby in Mali.

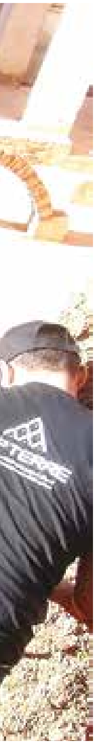
While it is becoming clear that raw earth now has a place in the sustainable and responsible building and architecture market, work still needs to be done to set up appropriate regulatory frameworks and standards which facilitate both the development of the private market and public procurement. It is in this sense that it is important to support the creation of networks of players and professionals such as FACT Sahel + to ultimately meet the growing needs of the African continent in terms of ecological and social transition in the field of human settlements.

Every year CAPTERRE trains nearly 250 people (students and professionals) and raises awareness among at least 2,500 members of the general public (including children). The activities take place in its premises in Timimoun or during building site training courses or major events (conferences and workshops)

Institutional strategies to support the use of local materials

CASE STUDY

A MAJOR GOVERNMENT COMMITMENT IN ALGERIA



Algeria has a great wealth of architectural and urban heritage mainly built in raw earth. After decades or even hundreds of years of use, this heritage was considered to be obsolete and was largely abandoned, a victim of standardisation of academic and vocational training in the building field which has excluded the learning of traditional building techniques and materials to the exclusive benefit of industrial materials. This heritage remains worthy or interest, however, both in and of itself and as a source of inspiration for the design of habitats with more eco-responsible virtues.

Created in 2012 by the Algerian Ministry of Culture, the Centre Algérien du Patrimoine Culturel Bâti en Terre (CAPTERRE) is responsible for rehabilitating the image of earthen architectures in particular and of local materials in general with the aim of preservation of earthen built heritage. Through this commitment, the Algerian state also wishes to explore the potential of a renewal of traditional know-how in earthen architecture as a lever for territorial development, which can bring economic, environmental, social and cultural benefits.

CAPTERRE's activity began in 2014. Since then, it has been conducting promotion and awareness actions intended both for the general public (including children) and for students and professionals in the building field (engineers, architects and artisans). It develops skills training and technical assistance for the rehabilitation of earthen built heritage, earth construction and the creation of earth-based material production sectors.

CAPTERRE also committed itself to a pilot project for rehabilitation of an earthen building as part of the Profas C+ programme (cooperation between Algeria and France). This operation was conducted in the historic area of the town of Timimoun, in the form of a field school. It was concluded with the drafting of a rehabilitation guide[1]. The experiment showed the benefits of rehabilitation compared to destruction/reconstruction both in economic terms, by halving the cost, and in environmental and heritage terms. It also demonstrated that preservation of heritage is fully compatible with adaptation to modern comfort. However, it revealed the need to restore the chain of knowledge and know-how throughout the local materials building sector. A similar experiment is in progress concerning the construction of a raw earth social housing unit with bioclimatic qualities.

After six years of activity, we see a strong renewal of interest in earthen construction in Algeria. Several university architecture and civil engineering departments are launching courses in earthen architecture and the number of dissertations and theses on the subject is growing.

The private sector, by way of companies and civil society, is also active with a considerable increase in the number of requests for technical assistance both in the heritage renovation field and in the new construction field. Another major challenge which must be taken up for the renewal of the sector is the development of its regulatory framework. This is the main purpose of a new project which should begin in 2021.

1 Terki, Y., Rakotomamonjy, B., Hacini, M., et al., 2019. Guide to rehabilitation of earthen housing in Timimoun. CRAterre ; CAPTERRE. https://hal.archives-ouvertes.fr/hal-02498416

Reconciling preservation of cultural heritage and development

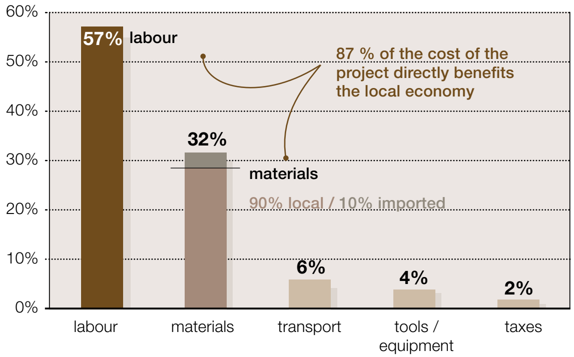
CASE STUDY

AN APPROPRIATE RETURN TO LOCAL RESOURCES, KILWA, TANZANIA

In the course of the 20th century, Tanzania experienced a considerable economic expansion which was accompanied by profound cultural changes, including in terms of housing. Although many high-quality buildings were built, difficulties still persist for certain sections of the population, particularly in rural and peri-urban areas, because building costs are too high. Furthermore, modernisation has taken place to the detriment of local identity and does very little to develop local resources and therefore employment.

In the strong heritage context represented by Kilwa Kisiwani, listed as a world heritage site, this contradiction between the potential of the local resources and their low level of use is particularly striking. The remains of the citadel of Kilwa are still in remarkably good condition whereas recent constructions show signs of weakness, due in particular to the effects of salt-laden sea winds.

Breakdown of the construction cost of the Kilwa Information Centre



In this context, and as part of a European project aimed at promotion of cultural heritage in Tanzania, a tourist information centre was built in 2015 in the city of Kilwa. Its design aimed to highlight the best of local architecture over the centuries by seeking inspiration as much in 20th century vernacular housing as in the 14th century ruins to be seen on this remarkable site. The materials are all from the local area. The building essentially consists of stones, lime, sand, earth, wood, bamboo and palm leaves. The false ceilings use coloured raffia mats produced by women, as an alternative to plywood. The result is highly appreciated. The building is considered to be comfortable and durable and its architecture is resolutely contemporary.

One of the most notable results of this building is the strong impact of the money spent on it on the local economy. 90 % of the money invested in this building was injected locally: salaries of masons and carpenters and extraction and delivery of materials.

The State, which owns the building, initially refused to allow the project to use local techniques and materials. Today, however, the staff of the Kilwa urban planning department are firmly convinced of its appropriateness and defend the benefits of using local resources and know-how both to preserve the identity of the place and to strengthen the local economy.

School in Begneimatou built almost exclusively in local materials (stones, earth and palm wood) with minimal input of industrial materials.

CASE STUDY

FACILITIES WELL INTEGRATED IN THE CULTURAL LANDSCAPE OF DOGON COUNTRY, MALI

The Bandiagara cliff site, commonly known as Dogon Country, has been listed as a World Heritage Site by UNESCO since 1989. This iconic site in Mali is a place in which cultural and nature tourism have enabled the development of economic activities beneficial for the whole population. However, despite their exceptional qualities, traditional architectural forms are increasingly being replaced by "international" style buildings. More particularly, the building of community and administrative facilities is beginning to have a negative impact on the scenic qualities of the site.

Conscious of this, the Bandiagara Cultural Mission (MCB), RADEV-Mali, AUDEX and local elected representatives wished to find construction and architectural solutions meeting contemporary needs while at the same time being better integrated in the cultural landscape. The ambition was also to propose models using local resources which could also be used by the populations to improve their habitat.

Post-flood rehousing programme in Bandiagara

Between 2007 and 2010, thanks to the support of the European Union, various additional activities were launched involving public and private players. A phase of analysis and inventory of building cultures was conducted to identify in the heritage and practices those elements which were most relevant and which were potentially adaptable to new needs. This work led to a series of "demonstration" buildings: a handicraft gallery, school, housing unit, etc. The evaluation of these projects in an iterative process enabled the results to be capitalised on in the form of a guide for the building of schools in Dogon Country, with the participation of representatives of several ministries (Culture, Education, Housing, etc.).

More than 30 buildings were built in the course of the project, providing opportunities for training and innovation, including a programme of 20 housing units in Bandiagara which were all used for training of executives, technicians and masons. All of these activities enabled the MCB and its partners to strengthen their capacities for promotion of cultural heritage to serve local sustainable development.

SUMMARY TABLE OF CASE STUDIES

PROJECT	**Accrediting local materials and know-how and restoring inhabitants' pride** (p. 52 and 53)	**Combating precarious housing in urban environments** (p. 54 and 55)	**Using local resources to enable populations to (re)house themselves** (p. 56 and 57)	**Promoting eco-responsible architecture in line with local needs** (p. 58 and 59)	**Encouraging sustainable and responsible procurement** (p. 60 and 61)	**The iterative approach: an essential corollary to the territorial analysis** (p. 62 and 63)	**Improving the resilience of populations in the face of disasters and climate change** (p. 64 and 65)
OBJECTIVES	• Improving the quality of housing by revitalising building practices using local materials	• Supporting and improving the social production of housing in areas of uncontrolled urbanisation	• Assisting rural migrants in urban areas in access to decent housing • Contributing to an improvement of housing conditions following a cyclone	• Combating deforestation by reducing the use of building timber • Improving the performance and durability of building systems	• Supporting the small-scale timber sector to make it more viable • Reducing the contribution of small-scale logging to forest degradation	• Combating deforestation by reducing the use of timber in construction • Developing reliable and appropriable alternative building solutions	• Co-developing adaptation solutions for building • Improving local building practices and strengthening capacities
ADVANTAGES OF LOCAL MATERIALS	- combating deforestation - improvement of the durability of buildings through better design and execution - potentials for the setting up of mutual-aid and self-building systems - relocalisation of production and jobs	- setting up of a participatory procedure - self-building - improvement of living conditions - improvement of substandard housing	- building in a landlocked, insular or difficult-to-access area - empowerment of local populations and players - hybridisation of local materials and thermo-industrial materials	- improvement of non-sustainable existing practices and combating deforestation - reduction of construction costs and improvement of local economic benefits - improvement of the life span of buildings - improvement of the living conditions of populations and of access to basic infrastructures	- guaranteeing the renewability of the resource - improvement of the quality of building materials and of the durability of constructions - improvement of the economic sector and the players concerned	- development of high-quality, affordable, income-generating and replicable localised solutions - improvement of the durability of constructions - reduction of the impact of construction on the environment - building of model facilities for improvement of housing	- permanently improving the capacities of populations to deal with climate change by way of appropriate technical and social solutions - contribution to the disaster risk reduction (DRR) strategy - affordable and reproducible solutions for post-disaster reconstruction projects
CONDITIONS FOR SUCCESS	- initial assessment and support of the stakeholders - linking between technical and social innovation - developing practical training through the building site, among other things - social and economic impact of the project beyond the direct beneficiaries	- initial assessment and decision-making aid - awareness-raising, technical support and reinforcement of capacities - developing appropriate communication tools (workshops, technical data sheets, etc.) - ensuring continuity in backing and appraisal as well as institutional support	- appropriation of the project approach by the stakeholders - being pedagogical and taking the time to convince people - technical support - reproducibility of the models proposed once the project is completed	- decision-making aid based on a shared analysis and appropriation of the project by the stakeholders - setting up of additional activities: training, awareness-raising, etc. - reverse engineering - multi-year institutional, political and financial support	- sustainable management of the resource over its whole life cycle - strengthening of capacities at all levels - advocacy	- holistic approach and participatory territorial analysis - demonstration buildings and innovations (earthen arch, vault and dome) - acceptability and appropriateness of the solutions - reinforcement of skills and long-term commitment of institutions	- local diagnosis (identification of strengths, weaknesses, priorities and points for attention) - guaranteeing access to resources and their correct management - identifying and documenting good practices and traditional knowledge which are sources of innovations - developing experimentation and changing the status of tried and tested solutions (from temporary to "sustainable")
AREAS	rural and peri-urban areas and medium-sized towns across countries	peri-urban and unplanned urban areas	peri-urban areas and areas exposed to natural hazards; new unplanned urban areas	areas in which deforestation is a problem (pressure on forest resources)	Central Africa and areas whose forest cover permits this within a perspective of sustainable management	desert regions (Sahel) or desertifying regions, rural and urban areas	urban or rural flood-risk areas

Developing a Skills and Certification Standard for earth construction (p. 66 and 67)	**Linking habitat to quality of life** (p. 68 and 69)	**Local materials and technical and social eco-innovation** (p. 70 and 71)	**Evaluating to minimise the environmental impact of construction** (p. 72 and 73)	**Bringing players together for the development of local material sectors** (p. 74 and 75)	**Institutional strategies to support the use of local materials** (p. 76 and 77)	**Reconciling preservation of cultural heritage and development** (p. 78 and 79)
• Promoting eco-building trades • Improving the quality of constructions in local materials	• Incorporating knowledge on local materials in educational programmes • Contributing to the recognition of sustainable building trades	• Combating invasive plants by making use of them • Developing local solutions for adaptation to climate change	• Improving precarious housing in peri-urban areas • Reducing the impact of the building sector on climate change	• Networking players in the earth construction sector	• Contributing to the development of local materials through institutional support • Safeguarding and enriching knowledge on local materials	• Making local cultural heritage a resource for the future • Designing contemporary architectures based on local building cultures.
- alternatives to non-sustainable and environmentally damaging local practices - support for micro and very small businesses - improvement of the quality of constructions - improvement of remuneration	- implementation of high-quality sustainable solutions - very good resistance of earthen walls to gunfire (safety of occupants) - improved health conditions (hygrothermal comfort) - Skills-Based Approach (SBA)	- appropriate solutions at affordable costs for the market - good insulating property of Typha - exploitation of the good hygrothermal qualities of earth	- reduction of GHGE - sustainable architecture at minimum cost	- adaptation to the various climatic, geological, social and cultural contexts to meet the various needs of the continent in terms of human settlements - high-quality, healthy and ecological constructions	- interventions and salvaging of existing buildings rather than destruction/reconstruction - lever for territorial development - economic, environmental and social benefits - bioclimatic and thermal quality of earthen buildings	- availability of materials on site or nearby - 90% of expenditure reinvested locally (economic benefits) - restoration of the heritage values and attractiveness of the site - creation of income-generating activities and skills - economical solutions
- setting up of training sites - modification of the economic model of small-scale building (method of payment) - empowerment - skills-based approach (SBA) and vocational training	- analysis of traditional housing - inclusive awareness-raising, training and construction for the various players in the act of building - integrated social, technical and educational innovations - programme supported at national level	- involvement of stakeholders - taking into account of local constraints and specificities (climatic, human, etc.) - time for research, innovation and experimentation - prototyping and demonstrators	- scientific support and setting up of experiments - involvement of stakeholders in the project - support from organisations rooted in projects for social production of housing	- will of the stakeholders and players in the sector - organisation of interprofessional exchanges on earthen architecture - multidisciplinarity - desire for a change of scale and recognition	- promotion and valorisation actions - field schools - restoration of the chain of traditional knowledge and know-how - changing of the regulatory framework and institutional support	- appropriation of the project and co-construction with the stakeholders - analysis and inventory of local building practices and cultures - institutional support, local leadership and long-term commitment of funders and institutional players - training and awareness workshops, demonstration projects and experimentation
global	post-conflict or post-disaster region first and foremost but also continental	Sahel region and region along the River Senegal (possible applicability in other contexts depending on the case)	global urban fringes and rural areas	regional and national; global	traditional urban and rural fabric, North Africa	“world heritage” and “cultural heritage” sites, but also beyond

5

CONDITIONS AND LEVERS FOR APPROACHES FAVOURING LOCAL BUILDING MATERIALS

As we have been able to see throughout this work, local building materials present a high potential to meet the challenges of the African continent in terms of sustainable development. Large-scale development of their use is thus desirable, as it would make it possible to:

- contribute to combating climate change by reducing the environmental footprint, pollution, waste and resource depletion linked to building activities,
- mitigate the effects of climate change by the adoption of appropriate urban planning and architecture using high-quality local materials,
- meet the needs of countries, regions and towns for affordable infrastructures and housing,
- improve means of subsistence, opportunities for income-generating activities and employability at the local level in building projects, and
- facilitate the development of the sectors concerned and therefore of local economies.

The ambition we must have is to progress rapidly towards a low carbon society made up of resilient territories and promoting culture diversity. For this purpose, the initiatives undertaken in recent decades in many places across the continent constitute a solid foundation on which it is important to base ourselves. By looking at them in a reflective way which allows us to evaluate the results and draw the lessons of the successes and failures, it is now possible to develop efficient and effective technologies and methods of approach enabling the change of scale required to face up to the immensity of the needs concerned in a fully responsible way.

Top: Red Pepper House, Kenya Architect: Urko Sanchez Architecture
Opposite: Public building in Mayotte: mango shingle roofing, compressed earth blocks and basalt stones for the walls, raffia for the partitions.

2

A PRECONDITION: MAKING A PARADIGM SHIFT, FROM LOCAL MATERIALS TO LOCAL BUILDING CULTURES

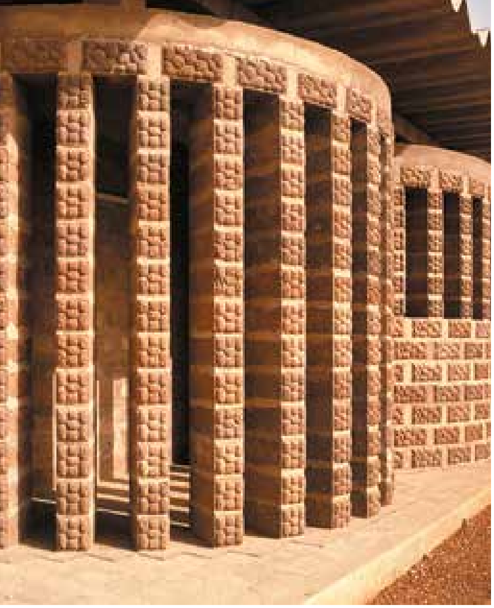
3

Development of the use of local materials can take place only if we work to change the general perception of local resources (physical and non-physical) and their added values. Adopting a "local materials" approach means in a way unlearning international standards and continuing to call them into question (a process already well underway). Even if these standards have proved to be inappropriate, they have too often completely erased all "vernacular" productions. This phenomenon is not specific to Africa. It also affects industrialised countries where the image of the standardised product has long been unquestionable. This destruction of "cultural diversity", like the more frequently cited destruction of biodiversity, is damaging for the planet. It deprives societies of solutions for the future.

It has therefore become vital today for people to regain faith in what they have "under their feet" and "within reach". We also need to give more consideration to the traditional productions developed by populations and local professionals based on the precise knowledge they have of their territory and the accumulated experience they have developed collectively, sometimes over several centuries. Local intelligences exist everywhere, and are all potential sources of inspiration concerning:

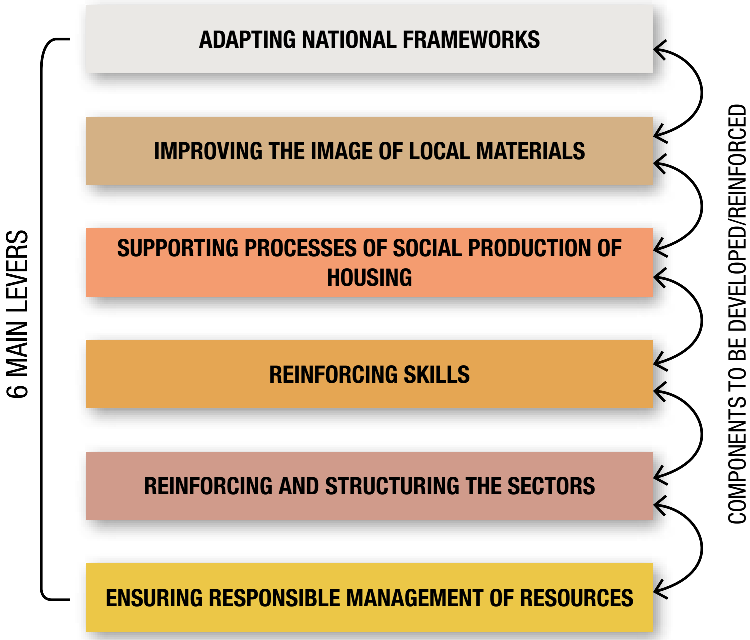
- location of human settlements: protection and access to water and other resources;
- organisation of towns and villages, neighbourhoods or hamlets;
- spatial and urban composition with places for shared activities, meeting and conviviality;
- culturally and climatically appropriate habitats;
- knowledge and know-how, including organisational knowledge which allows housing for everyone to be provided locally and which enables greater resilience when faced with crises.

An open attitude to these aspects is an important prerequisite both for properly taking into account the potentials of each territory and also for proposing solutions which make it possible firstly to draw maximum benefit from the strengths and capacities which already exist and secondly to meet the expectations of the populations concerned.



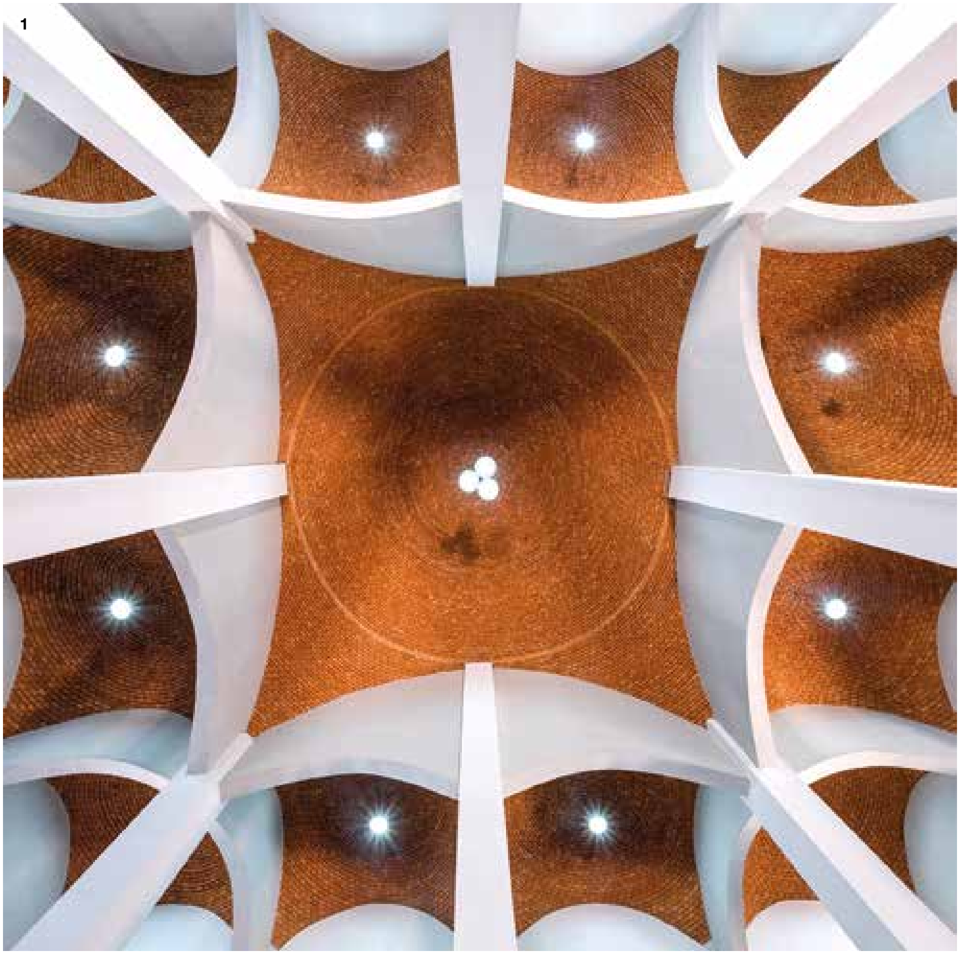
GENERAL RECOMMENDATIONS FOR A CHANGE OF SCALE AND SYSTEMIC CHANGE

Beyond this necessary paradigm shift, lasting and large-scale development of the use of local materials for building and land use planning necessitates the coordinated implementation of actions of diverse, complementary and coordinated natures. It is important to take into account the whole "ecosystem" and to facilitate the active participation of the stakeholders in both the public and the private sectors, in both formal and informal settings. This can be done by simultaneous and concerted use of six main levers:



1. RUCID College for Organic Agriculture. Architects: Localworks, Light Earth Designs
2. Building in hand-compressed CEB, near Dori, Burkina Faso
3. Compact housing in informal neighbourhood, Maputo, Mozambique. Architect: Casas Melhoradas

1



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1. HIKMA Cultural Complex, Dandaji, Niger. Architect: Atelier Masōmī and Studio Chahar
2. National Museum of Mali, Bamako

AT NATIONAL POLICY LEVEL

Most of the standards regulating the building sector essentially favour standardised and productivist approaches to the detriment of situated approaches, which are more flexible and adapted to realities in the field and are able to meet needs effectively, frugally and economically. The same applies to training standards at all levels: masons, technicians, engineers, architects, etc. It is therefore essential for governments to set up more favourable conditions, which implies:

- Including support for local materials sectors in the national strategic framework for sustainable development, incorporating incentives and facilitating measures;
- Adapting regulations and standards to accommodate the diversity of existing and possible solutions, through a performance-based and multidisciplinary approach;
- Setting up management systems for resource extraction and exploitation sites;
- Promoting and financing experiments, demonstrators and pilot projects;
- Facilitating access to financing for social production of housing;
- Proposing incentives in public procurement in all the ministries concerned: housing, education, health, agriculture, etc., and culture (cultural heritage);
- Promoting and supporting efforts to mobilise and unite players and sharing of knowledge;
- Backing the necessary changes to and updating of the academic and vocational education systems, aiming for better matching with markets, employment and national requirements;
- Supporting scientific and technical research and experimentation;
- Considering and developing communication actions (information and awareness) for a wider audience: events and promotion and experience-sharing campaigns, and the creation of resource centres.

AT LOCAL AUTHORITY LEVEL

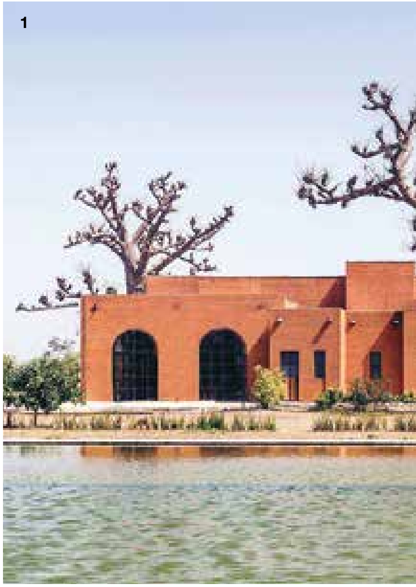
Elected representatives and technicians in local authorities are familiar with their territories, the local populations and realities in the field. They have very specific responsibilities In addition to certain national policy aspects cited above, they can contribute considerably to the development of the use of local materials to produce or improve human settlements via various activities such as:

- Mapping the available and possibly usable resources and identifying the potential conflicts of use (agricultural, urban, etc.) and the security requirements;
- Improving and securing access to these local resources, and implementing strategies for sustainable management of quarries (earth and stone) and exploitation sites for the bio-based materials already used (or usable) in construction (wood, straw, reeds and palms);
- Strengthening and supporting small-scale, sustainable local material suppliers and producers, by calling upon them regularly to perform work or recommending them to their contacts who are partners in development;
- Recognising, understanding and supporting existing practices and dynamics (including in informal settings) linked to the social production of housing: management of resources, production of materials, building, maintenance, repair and improvement;
- Facilitating the dissemination of knowledge and efforts to strengthen capacities (site training, apprenticeship, vocational training, etc.);
- Providing technical and financial assistance and supporting self-building for disadvantaged households and communities (if necessary with facilitation of access to land and securing of this access).

AT PROJECT PLAYER LEVEL

From the initial idea to its concretisation, project players must be constantly committed to the need to take into account the realities of local situations which present a great diversity and variability of materials and practices. Setting up “local materials” projects requires basing oneself on a good analysis and identifying the right questions in order to be able to take decisions in an informed way. What is the social and societal utility of the project? What needs must it meet? What is the nature of the problem to be solved or the situation to be improved? Is it a matter simply of answering a need or also of strengthening capacities and proposing solutions which can be reused by the populations and local artisans? What are conditions for success of such a project?
To succeed, it is therefore important to:

- Adopt an attitude of openness and listening: set aside preconceived ideas, seek first of all to understand, know how to observe and even learn from the field and its players (inhabitants, builders, etc.);
- Consider the whole of the formal and informal “local ecosystem” (public administrations, producers, suppliers, builders, training centres, artisans and inhabitants, etc.);
- Involve all the stakeholders concerned in the analysis, the thinking and the decisions which must be taken throughout the project;
- Conduct a concerted analysis in order to identify the existing capacities and practices, the initiatives and dynamics, the needs and the obstacles, both locally and nationally;
- Envisage proposing a range of technical and architectural solutions, as an accompaniment to existing dynamics and practices, while simultaneously imagining possibilities for adaptation to a variety of contemporary expectations and needs;
- Draw on earlier experiences, locally or in the sector and adapt them if appropriate;
- Adopt an iterative and reflective process associated with a gradual and controlled ramp-up of the project in order to facilitate adaptation and appropriation of technical, architectural, organisational, etc. proposals;
- Develop actions at different levels of intervention (material production projects, training projects, etc.) and envisage the complementarities (production, construction, training, technical guides, characterisation tests in the laboratory and in the field, etc.);
- Be prepared to operate on a long-term basis, because the building sector has a lot of inertia and is relatively slow-moving, and the test of time is essential for the target populations to be able to validate the proposals made to them and adopt them.



1. Villa Al Hamra, Senegal
Design: Atelier Koe
2. NIORO du RIP Professional Training Centre/ Senegal.
Architect: KHôZé

SPECIFIC POINTS FOR ATTENTION

In addition to the attention which must be paid to local specificities and therefore to the time devoted to the development of a good territorial diagnosis, it is useful to pay particular attention to a few points which it would be detrimental not to take into account. It is particularly recommended to:

- Consider the whole life cycle and production chain of potential local materials, from the supply sites through to the possible need for end-of-life recycling;
- Check that resources visible in the built heritage still exist. Some of them could have become difficult to exploit (exhaustion of quarries or disappearance of the resource) and the associated know-how may have disappeared or been partly lost;
- Take into account the changes observed in the local building culture (mode of inhabiting, construction, distinctive signs of appreciation), to be sure to go “in a progressive direction”;
- Do not hesitate, when appropriate, to propose mixed solutions combining local materials with thermo-industrial materials or prefabricated or even semi-industrial products: bricks, panels, insulators, joinery, ready-to-use coatings, etc.;
- Identify the formalisation needs (characterisation tests, technical guides, certification by the authorities, etc.) for validation of innovative building materials or techniques;
- Take into account the methods of payment of artisans which could constitute an obstacle (e.g. labour contracts calculated as a percentage of the cost of the materials);
- Be attentive to the levels of investment necessary for the setting up of the production processes, in relation to the capacities of the local players;
- Take into account the question of the management of the equipment (tools, machines, etc.) which must be acquired for its possible sharing over time between various players;
- Be reasonable from the technical point of view and regarding the performances expected for the materials, and adopt safety margins without excessively oversizing; pay attention to the protection of the most fragile materials during periods of bad weather;
- Carefully gauge the regular maintenance requirements of the proposed constructions, in line with the capacity of the users or groups of users to implement them: do methods of organisation exist or need to be constituted for this purpose?
- Devise complementary approaches: “top-down” through the setting up of a facilitation framework, regulatory provisions and incentives — and “bottom-up” to properly understand needs, raise awareness, reinforce and support;
- Be open to potential complementarities between formal and informal sectors;
- Identify the local institutional players who can be relied upon for the capacity reinforcement strategies and the dissemination of the results obtained.

LIST OF ORGANISATIONS IN THE FIELD OF LOCAL MATERIALS

SOUTH AFRICA
Eco Design – Architects & Consultants, architect, http://www.ecodesignarchitects.co.za/
Unit for Earth Construction / Earth Unit / Department of Architecture / University of Free State (UEC), academic, https://www.ufs.ac.za/natagri/departments-and-divisions/architecture-home/earth-unit-(eu)/background-of-earth-construction

ALGERIA
Atelier 3, architect, a3.architecture@yahoo.fr
Centre Algérien du Patrimoine Culturel Bâti en Terre (CAPTERRE), government organisation, http://capterre.dz/
Ecole Polytechnique d'Architecture et d'Urbanisme (EPAU), academic, http://www.epau-alger.edu.dz/
Mentouri University, Constantine Faculty of Architecture, academic, https://www.umc.edu.dz/index.php/fr/

ANGOLA
Don Bosco Salesian Congregation, training centre, salesianosangola.pj@gmail.com
Mauricio Ganduglia, architect, arqui.terra.ao@gmail.com
Lusiada University, Department of Architecture, academic, https://www.facebook.com/universidadelusiadadeluandaangola

BENIN
Ecole du Patrimoine Africain (EPA), academic, http://www.epa-prema.net/officiel/
Pôle Technique de Promotion des Matériaux Locaux (POTEMAT), academic, https://www.potemat.com/

BURKINA FASO
Atelier Drabo, construction company, atelierdrab@yahoo.fr
Ecole Supérieure Polytechnique de Kaya (ESPK), Cabinet de Conception d'Etudes et Réalisation d'Ouvrages Divers (2CEROD), design office, https://www.espkaya.com/
International Institute for Water and Environmental Engineering (2IE), academic, https://www.2ie-edu.org/
Keré Architecture, architect, https://www.kerearchitecture.com/
Université Saint Dominique d'Afrique de l'Ouest (USDAO), academic, https://www.usdao.org/?q=content/etudes-en-architecture
YAAM Solidarité, NGO, http://yaamsolidarite.blogspot.com/
ZI MATERIAUX, construction company, www.zi-materiaux.com

CAMEROON
Centre de Promotion des Artisans de Bafoussam (CEPAB), Promotion des Matériaux Locaux (PML), training centre, https://diocesedebafoussam.cm/vie-pastorale/cepab-centre-de-promotion-des-artisans-de-bafoussam
Center for International Forestry Research (CIFOR), research, https://www.cifor.org/locations/africa/
International Network for Bamboo And Rattan (INBAR), network, www.inbar.int
Mission de Promotion des Matériaux Locaux / Specialised Vocational Training Centre (MIPROMALO), government organisation, http://www.mipromalo.org/index.php/fr/

IVORY COAST
Art'Terre, architect, https://www.linkedin.com/in/philippe-romagnolo-2348b192/
Inades - formation, network, http://www.inadesformation.net/

EGYPT
Egyptian Earth Construction Association, NGO, https://www.facebook.com/EECApage/

GHANA
Building and Road Research Institute (BRRI), research centre, https://www.brri.org/
Hive Earth, construction company, https://www.facebook.com/hiveearthconstruction/
Kumasi National University for Science and Technology, College of Art and Built Environment, Faculty of Built Environment, academic, https://www.knust.edu.gh/

KENYA
African Organisation for Standardisation - Organisation Africaine de la Normalisation (ARSO-ORAN), standardisation body, https://www.arso-oran.org/
Centre for Heritage Development in Africa (CHDA), government organisation, https://www.facebook.com/Centre-for-Heritage-Development-in-Africa-143836212301936/
United Nations Environment Programme (UNEP), international organisation, https://www.unep.org/
United Nations Human Settlements Programme (UN-Habitat), international organisation, https://unhabitat.org/

MALAWI
14 trees, construction company, https://www.14trees.com/
Sam's Training Village, NGO, https://www.facebook.com/Sams-Village-1414840415409790/

MALI
Agence de Gestion, Recherche et Expertise en construction (AGREBAT), design office, https://agrebat.com/
ARCHITERRE, architect, http://www.a-architerre.com/atelier/architerre/
AUDEX, architect, https://fr-fr.facebook.com/

Non-exhaustive list of organisations involved in the field of local building materials in Africa. Although certain entities operate in several countries or across the continent, they are listed according to the location of their head office. Certain organisations based in France which work with partner institutions have been mentioned at the end of the list. This list does not reflect the diversity and the dynamics of the players in Africa and does not imply any recognition on the part of the authors. It is given for information and in accordance with current knowledge. Do not hesitate to inform us of any errors or omission.

AUDEXSARL/
École Supérieure d'Ingénierie, d'Architecture et d'Urbanisme (ESIAU), academic, https://esiau-mali.com/
Fédérer les Acteurs de la Construction en Terre au Sahel et dans les pays limitrophes (FACT Sahel+), network, https://www.factsahelplus.com/
Mission Culturelle de Bandiagara (MCB), government organisation, http://www.culture.gouv.ml/

MAURITANIA
Habitat et Développement en Mauritanie, construction company, https://www.facebook.com/Habitat-Et-D%C3%A9veloppement-En-Mauritanie-787728054670428/

MOROCCO
Agence Salima Naji, architect, https://www.facebook.com/Agence-Salima-Naji-Architecte-214087665440465/
Centre for the Conservation and Rehabilitation of the Architectural Heritage of Atlas and sub-Atlas zones (CERKAS), government organisation, https://www.facebook.com/Cerkas-103882341320544/
Hassania School of Public Works (EHTP), academic, http://www.ehtp.ac.ma/
National School of Architecture / La Terre (ENA / PATerre), academic, http://www.enarabat.ac.ma/
Laboratoire Public d'Essais et d'Etudes (LPEE), research centre, http://www.lpee.ma/
Le Centre de la Terre / Terra Janna, training centre, https://terrajanna.com/terre/

MOZAMBIQUE
Young Africa Mozambique, training centre, https://youngafrica.org/act/mozambique

NIGER
Association Nigérienne de Construction Sans Bois (ANCSB), NGO, https://ancsb.org/
Atelier masomi, architecture agency, http://www.ateliermasomi.com/
Terre d'Afrique et Architecture, project, https://terredafriqueetarchitecture.wordpress.com/

NIGERIA
Abubakar Tafawa Balewa University, Faculty of Environmental Technology (ATBU – SET), academic, https://www.atbu.edu.ng/web/front/academics/faculties/faculty-of-environmental-technology
Centre for Earth Construction Technology (CECTech), government organisation, https://www.facebook.com/ncmmng/

UGANDA
Makerere University / Department of Architecture (MUK), academic, https://cedat.mak.ac.ug/graduate-programmes/master-of-architecture/
Uganda Technical College (UTC), training centre, https://utcbushenyi.ac.ug/building-civil-engineering-ndbce/

DRC
Amicale des autoconstructeurs ruraux (AMICOR), network/construction company, https://www.linkedin.com/in/adolphe-mayogi-022a2082/
Caritas Développement Lubumbashi, Responsible Green Building department, NGO, https://www.caritasdev.cd
Kongo University, Faculty of situated architecture, urban planning and land use planning, academic, https://universitekongo.cd/index.php/faculte-darchitecture-urbanisme-et-amenagement-du-territoire/

SENEGAL
#Elementerre, construction company, http://www.elementerre-sarl.com/
Collectif Worofila_Architecture terre Sénégal, architect, https://www.facebook.com/worofila
PNEEB / TYPHA project, project, https://www.tyccao-typha.org/

TOGO
Centre de la Construction et du Logement (CCL), research centre, http://www.ccltogo.com/ - https://urbanisme.gouv.tg/node/397
Centre International de formation en architecture de terre (CIFA-Terre), training centre, https://www.facebook.com/pg/Centre-International-De-Formation-En-Architecture-De-Terre-CIFA-Terre-217848985637306/posts/
Ecole Africaine des Métiers de l'Architecture et de l'Urbanisme (EAMAU), academic, https://www.eamau.org/

FRANCE
Architecture Sans Frontières – International (ASF International), network, https://www.asfint.org/en
International Centre on Earth Construction (CRAterre), NGO, www.craterre.org
Development Workshop (DW), NGO, https://www.dwf.org/
Ecole Nationale Supérieure d'Architecture de Grenoble - Architecture, Environment and Building Cultures research unit (AE&CC/ENSAG), academic, https://www.grenoble.archi.fr/
La Voute Nubienne, NGO, https://www.lavoutenubienne.org/
French Partnership for Cities and Territories (PFVT), network, https://www.pfvt.fr

BIBLIOGRAPHY AND RESOURCE MATERIALS

The works mentioned here do not constitute a complete and systematic bibliography. They are far from covering the entirety of the subject and from representing the wealth of literature produced on local materials. For obvious reasons of space, a choice had to be made. Do not hesitate to inform the authors of works which should have featured in the list.

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NOTES

Villa Al Hamra, Senegal
Design: Atelier Koe

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This work concerns the theme of “sustainable cities and territories” evoked by many players in France, in Africa and internationally. It is intended primarily for “Habitat” decision-makers and officials in the ministries and local and regional authorities concerned, but also for other stakeholders in the sector (craftsmen and entrepreneurs, professional organisations, academic and professional training centres, research centres, NGOs, etc.).

Drawing on the experience of the last few decades in this field, it aims to promote a Sustainable Development approach to meet the immense construction needs in Africa, based on rational and sustainable use of local materials.

For this purpose, it presents in a concise and educational way the benefits, the questions which are raised and the prerequisite conditions for the use of these materials. In addition to examples of technical solutions illustrated by an overview of the potential (bio-based and geosourced) resources of the territories concerned, it provides some elements for analysis of the impact of local short production chains and some methodological elements. It also highlights the need for matching between architectural design and the specific characteristics of the materials available locally, which could be summarised as “the right material in the right place”.

CRAterre

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